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COMPARISON OF TAIL AND WING-TIP SPIN-RECOVERY

PARACHUTES AS DETERMINED BY TESTS IN THE

LANGLEY 20-FOOT FREE-SPINNING TUNNEL

By Robert W. Kamm and Frank S. Malvestuto, Jr.

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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

~~RESTRICTED~~ REPORT

COMPARISON OF TAIL AND WING-TIP SPIN-RECOVERY
PARACHUTES AS DETERMINED BY TESTS IN THE
LANGLEY 20-FOOT FREE-SPINNING TUNNEL

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SUMMARY

Tests of spin-recovery parachutes on six models of typical fighter and trainer airplanes were conducted in the Langley 20-foot free-spinning tunnel to obtain data for correlating model and full-scale results. Parachutes attached to the tail of the models, to the outer wing tip (left wing tip for a right spin), to the inner wing tip, and to both wing tips were tested.

The results indicated that parachutes of the same size and type were more effective as spin-recovery devices when they were attached to the outer wing tip in the spin than when they were attached to the tail. The diameter of the outer wing-tip parachute required for a 2-turn recovery by parachute action alone varied from 4 to 7 feet. Parachutes attached to the inner wing tip would not effect recovery. When parachutes attached to both wing tips were used for recovery, the parachute diameters required were of the same order as for tail parachutes. The diameter of the tail parachute required for a 2-turn recovery by parachute action alone varied from 6.5 to 12.5 feet for the airplane designs used.

INTRODUCTION

In order to obtain data for a correlation between model and flight tests of spin-recovery parachutes, tests were conducted with six airplane models of single-engine design. The effectiveness of both tail and wing-tip parachutes as spin-recovery devices was determined for these models. The spin-recovery parachute is normally

used only as a temporary emergency safety device during spin demonstrations so that rapid recoveries from uncontrollable spins may be obtained. Available flight and model test data on the use of tail parachutes as spin-recovery devices are presented in reference 1, and the results of these tests indicated that airplanes weighing between 7500 and 14,000 pounds require tail parachutes having diameters of approximately 8 feet (based on a drag coefficient of 1.02) and towline lengths between 20 and 50 feet in order to obtain satisfactory recoveries by the use of the parachutes alone.

Results are presented herein of the investigation of the six airplane models, designated models A, B, C, D, E, and F, with spin-recovery parachutes attached either to the tail or to the wing tips of the models for the normal loading conditions. On each model, tail and wing-tip parachutes of various sizes were tested with several lengths of line connecting the parachute to the airplane. The results are analyzed to show the minimum satisfactory size of the parachute and the optimum length of the towline for spin-recovery-parachute installations. Brief additional tests were conducted to investigate the effect of mass variations on the effectiveness of the spin-recovery parachutes when attached to the wing and the effect on recovery of simultaneously opening a tail parachute and neutralizing the rudder. For one model, tests were made at two equivalent spin altitudes to determine whether altitude critically affected tail - or wing-tip-parachute effectiveness.

Two of the models (A and B) had been used in the investigation of tail parachutes reported in reference 1 and tests of tail parachutes were accordingly not repeated for these two models. The results obtained in the previous investigation are included however in the present paper.

SYMBOLS

b	wing span, feet
m	mass of airplane, slugs
I_X , I_Y , and I_Z	moments of inertia about the X, Y, and Z body axes, respectively, slug-feet ²

$\frac{I_X - I_Y}{mb^2}$	inertia yawing-moment parameter
$\frac{I_Y - I_Z}{mb^2}$	inertia rolling-moment parameter
$\frac{I_Z - I_X}{mb^2}$	inertia pitching-moment parameter
α	acute angle between vertical axis and thrust line (approximately equal to absolute value of angle of attack at plane of symmetry), degrees
ϕ	angle between span axis and horizontal, degrees
V	airplane true rate of descent (estimated by scaling from model values), feet per second
Ω	airplane angular velocity about spin axis (estimated by scaling from model values), radians per second
D	drag of parachute, pounds; also diameter of parachute spread flat
q	dynamic pressure $\left(\frac{1}{2}\rho v^2\right)$
ρ	air density, slugs per cubic foot
C_D	drag coefficient of parachute $\left(\frac{D}{qS_p}\right)$
S_p	surface area of parachute, square feet
C_l	rolling-moment coefficient $\left(\frac{L}{qbs}\right)$
S	wing area, square feet
L	rolling moment about longitudinal body axis, foot-pounds
C_n	yawing-moment coefficient $\left(\frac{N}{qbs}\right)$
N	yawing moment about normal body axis, foot-pounds

APPARATUS AND MODELS

The tests were performed in the Langley 20-foot free-spinning tunnel, the operation of which is similar to that of the 15-foot free-spinning tunnel described in reference 2.

Models A, B, C, and D, used in the investigation, represented typical fighter airplanes, whereas models E and F represented typical trainer-type airplanes. The design characteristics of the airplanes represented by the models are presented briefly in table I and three-view drawings of the models used in the tests in the Langley 20-foot free-spinning tunnel are presented as figures 1 to 6.

The general construction of the spin models is described in reference 2. Briefly, the models, constructed of balsa, are dimensionally representative of the corresponding airplane and are ballasted for dynamic similarity to the corresponding airplane by the installation of proper-size lead weights at suitable locations.

The model parachutes used for most of the tests were the same ones used for the investigation reported in reference 1 and were made of parachute silk. The skirts of these parachutes were not hemmed, nor were the parachutes made of individual panels. They were circular and when spread out on a flat surface formed a disk. Circular vent openings were cut in the center of the parachutes and were made one-twelfth of the diameter of the parachute when spread out on a flat surface in order to simulate approximately full-scale vent openings. Eight shroud lines of equal length were evenly spaced on the periphery of the parachute. The shroud-line lengths were made 1.35 times the diameter of the parachute because it has previously been found (reference 3) that with shroud lines greater than 1.25 times the diameter, the drag coefficient varies only slightly with change in shroud-line length.

In order to determine whether details of construction affected the action of the parachutes, a few parachutes were constructed to simulate more nearly full-scale parachutes - that is, the skirts were hemmed

and the parachutes were made of individual panels sewed together (fig. 7). Ten panels and ten shroud lines were arbitrarily used for these parachutes.

TESTS

The spin-testing technique used in the Langley free-spinning tunnels is described in detail in reference 2. Briefly, the models with the rudder set for the spin are launched by hand (this procedure supersedes the launching-spindle method described in reference 2) in a spinning attitude into the vertical upward air stream of the tunnel. The airspeed is adjusted to equal the normal rate of descent of the model. A remote-control mechanism is installed in the models to actuate the controls or to release the parachute for recovery attempts.

For tests with the parachute mounted at the tail, most recoveries were attempted by ejecting the parachute from a container (as described in reference 1). The rudder was kept with the spin during recovery so that the effectiveness of the parachute alone could be obtained. In addition, a number of tests were conducted in which, for recovery, the rudder was neutralized at the same time that the parachute was opened so that the combined effect of opening the parachute and neutralizing the rudder could be evaluated.

For the investigation of wing-tip parachutes, the parachutes were mounted on the upper surface of the wing near the wing tip. Figure 8 shows the type of installation used. For attempted recoveries, a rubber band holding the packed model parachute to the wing was released by the remote-control mechanism and the parachute was opened merely by the action of the air stream over the wing.

Tests were made to determine the parachute effectiveness with the loading along the wings and along the fuselage varied for several of the models. Table II presents the mass parameters of the models for the normal loading condition and for the alternate loading conditions. The parameters $\frac{I_x - I_y}{mb^2}$, $\frac{I_y - I_z}{mb^2}$, and $\frac{I_z - I_x}{mb^2}$ are indicative of the relative distribution of the mass along the three body axes.

As previously mentioned, tests of both tail and wing-tip parachutes were made for one model ballasted to represent the corresponding airplane at altitudes of 10,000 and 20,000 feet.

RESULTS AND PRECISION

The results of the investigation are summarized in tables III to VIII and figures 9 to 27.

The drag coefficients of the model parachutes were found to be approximately 0.73 (based on flat area) by determining in the tunnel the rates of descent of the freely falling model parachutes with various weights attached. The full-scale-parachute diameters referred to herein were obtained by scaling up the model values, inasmuch as at the present time only limited data are available on the correct value of the drag coefficients of freely falling full-scale parachutes. Reference 3 indicates that the drag coefficient 0.73 obtained for model parachutes is within the range of values of drag coefficients 0.62 to 0.79 obtained for freely falling full-scale silk antispin parachutes. In reference 1, the parachute diameters were corrected for a difference in drag coefficient between model and full-scale parachutes on the assumption that the drag coefficient of full-scale parachutes was 1.02. In order to select the full-scale parachute, it is therefore necessary to know the drag coefficient of the full-scale parachute and to correct the parachute diameter for any difference in drag coefficient between the full-scale parachute and the model parachute to obtain the same drag. An example showing the method used to determine the correct diameter for full-scale parachutes, based on drag coefficients of model parachutes, is given in the appendix.

The parameters given in table III present the steady-spin characteristics of the models just prior to attempted recoveries. All the models used in the present investigation had previously been tested and repaired extensively. As a result, the steady-spin characteristics presented in table III are somewhat different from those obtained during the previous routine investigations of the models but are considered to be accurate enough to give dependable results for the present investigation.

The steady-spin parameters presented in table III are believed to be the true values given by the model within the following limits:

α , degrees	± 1
ϕ , degrees	± 1
V , percent	± 2
Ω , percent	± 2

Most of the recovery data plotted in the figures were obtained from film records and are believed to be the true values given by the models within $\pm \frac{1}{4}$ turn. A few of the recoveries were obtained by visual estimates and are believed to be accurate within $\pm \frac{1}{2}$ turn.

DISCUSSION

Parachute Construction

The results of brief tests that were conducted to compare the drag coefficients and effectiveness of the plain fabricated model parachutes used in the investigation reported in reference 1 with the drag coefficients and effectiveness of parachutes more nearly approximating full-scale construction, as shown in figure 7, showed that the drag coefficients of the differently constructed parachutes were similar and that the parachutes had the same effectiveness of operation during model tests. Most of the tests were therefore conducted with the plain fabricated parachutes since these parachutes were readily available in all sizes.

Tail Parachutes

The variation of turns for recovery with tail-parachute diameter for the normal-control configuration for spinning (rudder full with the spin, elevator full up, and ailerons neutral), for the elevator-neutral position (aileron neutral), and for the elevator-down position (aileron neutral) are presented in figures 9, 10, and 11, respectively. Recoveries were attempted by ejecting the parachute from a cylinder installed near the tail. In figures 9, 10, 11, and the following graphs, the arrows on the ends of some of the curves

mean that the model did not recover in the number of turns indicated. Parts of the curves falling between points representing a diameter that gave recovery and one that did not give recovery are dashed to indicate that the fairing of that part of the curve is questionable.

For a constant towline length the turns for recovery generally decreased as the tail-parachute diameter increased. The approximate full-scale-parachute diameters required to effect a recovery from the spin in 2 turns at the normal-control configuration are summarized in table IV and varied from 6.5 to 12.5 feet.

For models A, B, and C, spins with the elevator up required somewhat larger tail parachutes than did spins with the elevator neutral or down, whereas for models D, E, and F, the opposite was true (figs. 9 to 11). The explanation of this result is not apparent.

The length of the towline of tail parachutes had a marked effect on the number of turns for recovery, as may be observed from figure 12, which presents results for elevator-up spins. (Although not presented, the same type results were obtained with the elevator neutral or down.) Towline lengths between 20 and 50 feet full scale were most satisfactory because within these limits the variation of turns for recovery with towline length was small. This result is consistent with the conclusion of reference 1.

The effect of simultaneously opening a tail parachute and neutralizing the rudder is presented in table V for the up, neutral, and down positions of the elevator (ailerons neutral). Neutralizing the rudder in conjunction with opening the parachute was somewhat beneficial for all conditions tested.

As previously mentioned, reference 1 indicates that an 8-foot tail parachute (based on a drag coefficient of 0.73 instead of 1.02, the diameter of the parachute would be $9\frac{1}{2}$ feet instead of 8 feet) would effect a satisfactory (2-turn) recovery from the steady spin for airplanes weighing between 7500 and 14,000 pounds. The current tests indicate that the diameter of the tail parachute required for a satisfactory recovery from the spin is not constant nor

does it vary directly with the weight of the airplane. For example, airplane C having a gross weight of 7406 pounds required a 9-foot tail parachute and airplane D having a gross weight of 8011 pounds required a 12.5-foot tail parachute, but airplane B having a gross weight of 9277 pounds (1266 pounds more than the gross weight of airplane D) required a 9-foot parachute for satisfactory recovery from the spin.

Parachutes Mounted on Outer Wing Tip

The wing-tip parachutes, mentioned previously, were mounted on the upper surface of the wing near the wing tip, as shown in figure 8. In some cases, the protuberance of the packed parachute affected the steady spin of the model, and for each series of tests determination of the location at which to place the parachute pack was necessary so that the steady-spin characteristics of the model were not changed. For this reason, installing the parachutes on the surface of the wing of airplanes is not considered advisable. The parachute packs should instead be placed inside the wing and provision should be made to eject the parachutes into the air stream.

The variation of turns for recovery with parachute diameter for parachutes mounted on the outer wing tip (left wing tip in a right spin) for spins with the elevator up, neutral, and down are presented in figures 13, 14, and 15, respectively. Figure 16 shows the action of the outer wing-tip parachute in effecting a recovery from the spin. The towline lengths were generally made approximately equal to the semispan of the airplanes. In general, for all models a larger wing-tip parachute was required to effect recovery from spins with the elevator neutral or down than from spins with the elevator up. The diameters of the outer wing-tip parachutes required to effect a recovery in 2 turns from the spin at the normal control configuration for spinning are given in table IV for all the models and varied from 4 to 7 feet.

The results in table IV indicate that for the models tested, a parachute attached to the outer wing tip is more effective as a spin-recovery device than the same size parachute attached to the tail.

Figure 17 presents test results showing the variation of turns for recovery with towline length for wing-tip parachutes for the elevator-up spins. Towline length did not appear to influence the effectiveness of the parachutes appreciably. When no towline was used (or when the towline was very short), however, the parachutes sometimes fluttered in the wake of the wing as shown in figure 18 (frames 14 and 15) and did not function properly. If long towlines (towlines approximately equal to or greater than wing span) are used to attach the parachute to the wing tip, there is the possibility of the parachute and towline fouling the tail or fuselage of the airplane as shown in figure 19 (frames 43 and 44). It is recommended, therefore, that the length of the towlines be such that when fully extended the parachute just misses both the tail and the fuselage.

Parachutes Mounted on Inner Wing Tip

Brief tests (test results not presented) made with parachutes attached to the inner wing tip (right wing tip in a right spin) indicated that parachutes on the inner wing tip will not effect a satisfactory recovery from the spin. For some cases use of the parachutes was observed to flatten the spin. It is, therefore, very important to use care in opening the correct wing-tip parachute for attempted recoveries from spins.

Parachutes Mounted on Both Wing Tips

The simultaneous opening of two identical parachutes, one mounted on each wing tip, would eliminate the hazards encountered in using only one wing-tip parachute - the hazards are the possibility of opening the wrong parachute or the danger of being forced into a spin in the opposite direction by a large wing-tip parachute (see fig. 20) if the parachute is not released immediately after recovery. The effect of parachute diameter for elevator-up, elevator-neutral, and elevator-down spins on turns for recovery attempted by simultaneously opening parachutes on both wing tips is presented in figures 21, 22, and 23, respectively. Satisfactory recoveries from the elevator-up spins could not be effected for models A, B, E, and F with the largest parachutes tested. The results for models B, E, and F were not plotted because, for the size of the

parachutes investigated, recoveries could not be obtained from spins. Models C and D required approximately 8-foot parachutes for a 2-turn recovery. The results presented in figures 21 to 23 indicate that moving the elevator full down in conjunction with opening the parachutes may be desirable in order to obtain recovery from spins by simultaneously opening parachutes mounted on both wing tips.

A comparison of the results presented in table IV shows that much larger parachutes will be required to obtain satisfactory recoveries by opening parachutes mounted on both wing tips than by opening one parachute mounted on the outer wing tip. In order to obtain satisfactory recoveries by opening parachutes fastened to each wing tip, the parachute diameters may have to be as large or larger than the diameter for tail parachutes.

Figure 24 shows the effect of towline length on turns for recovery attempted by the use of parachutes mounted on both wing tips for the elevator-down condition. As was the case for parachutes mounted on the outer wing tip, towline length generally had little effect on turns for recovery. When the towlines were too long (equal to the span), however, they frequently became tangled with each other and did not effect recovery. The results presented in figure 24 are for the cases in which the parachutes opened properly without tangling.

Loading Variations

In order to determine whether variations in loading of the models would influence the effectiveness of parachutes, tests were made on some of the models with the loading varied along the wings and fuselage.

Brief tests of outer wing-tip parachutes were made on four of the models with the loading along the wings increased and on one of these four models with the loading along the fuselage increased. The results, which are summarized in table VI, indicate that extreme increases in the loading along the wings had little effect on the recoveries obtained by opening parachutes fastened to the outer wing tip for models A and E but had an adverse effect for models C and F. A moderate increase in the loading along the fuselage had little effect on recoveries of model F.

Table VII summarizes the effect of loading variations on the recoveries obtained by simultaneously opening parachutes mounted on both wing tips for models C, E, and F. With the loading along the wings increased for model C, recoveries were slower than for the normal loading condition. As mentioned previously, recoveries could not be effected for models E and F in their normal loading conditions, and increasing the loading along the wings of these models had no noticeable effect on recovery. A moderate increase in loading along the fuselage had no appreciable effect on the recoveries of model F.

Brief tests were made with model B to determine the effect of loading variations on recoveries attempted by simultaneously opening a tail parachute and neutralizing the rudder. The results are presented in table VIII and show that moderate increases or decreases of mass along the fuselage and wings did not appreciably affect the recoveries.

Effect of Test Altitude

Brief tests were conducted with model E to determine whether variations in test altitude would influence the effectiveness of spin-recovery parachutes for this airplane. The model was tested at simulated test altitudes of 10,000 and 20,000 feet. The results are presented in figures 25 to 27. Based on these meager results, there appears to be little effect of altitude on the optimum size of wing-tip or tail parachute required for satisfactory recovery. The test altitude also had little effect on the variation of turns for recovery with towline length for parachutes attached to the tail.

Action of Spin-Recovery Parachutes

Tail parachutes.- The action of tail parachutes in effecting recoveries from spins has been discussed in reference 1. Briefly, with long towlines (towlines longer than 50 feet, full scale) the parachute towlines tend to incline toward the spin axis. With short towlines (less than 20 feet, full scale) the parachute towlines tend to remain aligned with the fuselage axis. With towlines between 20 and 50 feet long, the parachutes usually ride approximately over the tail of the model, although they may oscillate from this position.

Reference 1 indicates that as the towline may usually incline away from the plane of symmetry toward the inner wing tip, the parachute exerts yawing as well as pitching moments but that the effectiveness of the parachute results more from the antispin yawing moment than from the pitching moment produced.

Outer wing-tip parachutes.- The typical action of a parachute fastened to the outer wing tip in effecting recovery is shown in figure 16. Frame 15 of figure 16 and frames 22 and 34 of figure 19 show that the parachute towline tended to incline away from the fuselage axis toward the vertical axis. Frame 20 of figure 16 and frames 16 and 28 of figure 19 show that the parachute towline generally tended to remain parallel to the X-Z plane of the model, although the parachute did oscillate. The motion-picture records of all the tests indicate that both rolling and yawing moments were set up by the parachute. As a matter of interest, the estimated yawing and rolling moments contributed by parachutes were compared with corresponding moments contributed by rudder reversal and full aileron deflection. The moments resulting from rudder and aileron deflection were computed by use of average moment-coefficient values for angles of attack in the spinning range obtained from force tests on models of other airplanes. For cases in which the outer wing-tip parachute was effective, the rolling-moment coefficient C_l due to the parachute was in the direction to roll the model into the spin and varied from 0.010 to 0.015, which is less than one-half the typical rolling-moment coefficient of 0.03 developed by full aileron deflection. The yawing-moment coefficient C_n due to the parachute was approximately equal to the typical yawing-moment coefficient of 0.015, which would be expected from full reversal of the rudder. The effectiveness of wing-tip parachutes appears to result therefore more from the yawing moments set up by the parachute than from the rolling moments.

Reference 4 states that when the mass of an airplane is distributed chiefly along the fuselage, setting the ailerons with the spin will assist recoveries obtained by rudder reversal, whereas when the mass is distributed chiefly along the wing, setting the ailerons with the spin may greatly retard recoveries. A parachute attached to the outer wing tip, by inducing a pro-spin rolling moment, is in effect simulating the aileron-with-spin configuration of the airplane. It would be

expected, therefore, that recoveries obtained by the use of an outer wing-tip parachute would be retarded by extending mass along the wing of the airplane, if the yawing moment due to the parachute and the yawing moment due to rudder reversal are approximately equal. This adverse effect of extending mass along the wing was obtained for models C and F, whereas for models A and E very little effect on turns for recovery was obtained by change in distribution of mass.

CONCLUSIONS

Results of tests of spin-recovery parachutes made on six models of typical fighter and trainer airplanes to obtain data for correlating model and full-scale results indicated the following conclusions:

1. Parachutes were more effective as spin-recovery devices when they were attached to the outer wing tip in the spin than when they were attached to the tail. The diameter of the tail parachute required for a 2-turn recovery by parachute action alone varied from 6.5 to 12.5 feet, whereas the diameter of the outer wing-tip parachute required for a 2-turn recovery by parachute action alone varied from 4 to 7 feet.
2. When a parachute attached to the inner wing tip in the spin was opened, the parachute would not effect recovery.
3. When parachutes attached to both wing tips were used, the parachute diameters required were approximately the same size as for tail parachutes.
4. For wing-tip parachutes it is recommended that the towline length be such that when fully extended the parachute just misses both the tail and fuselage.
5. For tail parachutes the towline should be between 20 and 50 feet long.
6. Neutralizing the rudder at the same time that the tail parachute was opened gave faster recoveries than were obtained by opening the parachute alone.

7. For two of the four models tested with varied mass distribution, extension of mass along the wings had an adverse effect on recoveries attempted by opening parachutes attached to the outer wing tip.

8. Tests conducted with one model at two equivalent test altitudes (10,000 and 20,000 ft) showed no noticeable effect of a change in altitude on the optimum size of wing-tip or tail parachute required for satisfactory recovery.

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APPENDIX

METHOD OF CORRECTING PARACHUTE SIZE FOR DIFFERENCES

IN DRAG COEFFICIENTS

The model tests indicate that for model C, for example, a 9.0-foot parachute fastened to the tail will be required to effect a recovery in 2 turns by merely opening the parachute. This diameter is based on a drag coefficient C_D of 0.73 for the parachute. If it is planned to use a parachute of similar shape but of different material so that the parachute has a drag coefficient of 0.56, the area must be larger in the ratio of 0.73/0.56. The parachute diameter must

therefore be larger in the ratio $\sqrt{\frac{0.73}{0.56}} = 1.14$, which gives a parachute diameter of 10.3 feet.

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TABLE I
COMPARISON OF FULL-SCALE DESIGN CHARACTERISTICS OF MODELS TESTED

[Normal loading conditions]

Airplane	Test altitude (ft)	Gross weight (lb)	c.g. (percent M.A.C.)	Span (ft)	Wing area (sq ft)	Wing loading, W/S	I_x (slug-ft ²)	I_y (slug-ft ²)	I_z (slug-ft ²)
A	10,000	11,860	27.8	40.8	300.0	42.3	13,867	13,047	25,841
B	10,000	9,277	26.8	41.4	275.4	33.3	8,920	9,181	17,224
C	6,000	7,406	31.3	34.0	213.0	36.3	5,201	6,077	10,704
D	12,000	8,011	28.6	37.3	236.0	33.9	4,903	7,237	11,441
E	10,000	4,227	29.1	42.0	239.0	17.7	2,659	4,122	6,201
F	10,000	4,467	26.2	41.0	246.2	18.1	2,741	4,237	5,681

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TABLE II

MASS PARAMETERS OF MODELS TESTED FOR NORMAL AND
ALTERNATE LOADING CONDITIONS

Airplane	Loading condition	$\frac{I_X - I_Y}{mb^2}$	$\frac{I_Y - I_Z}{mb^2}$	$\frac{I_Z - I_X}{mb^2}$
A	Normal	14×10^{-4}	-210×10^{-4}	196×10^{-4}
A	I_X and I_Z increased 50 percent I_X	125	-325	200
B	Normal	-6	-163	169
C	Normal	-43	-160	203
C	I_X and I_Z increased 115 percent I_X	173	-389	216
D	Normal	-67	-121	188
E	Normal	-63	-90	153
E	I_X and I_Z increased 206 percent I_X	170	-323	153
F	Normal	-64	-62	126
F	I_Y and I_Z increased 30 percent I_Y	-118	-64	182
F	I_X and I_Z increased 124 percent I_X	82	-206	124

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TABLE III

STEADY-SPIN CHARACTERISTICS OF MODELS JUST PRIOR TO ATTEMPTED RECOVERIES

[Controls set at ailerons neutral, rudder with the spin]

Airplane	Loading condition	Rudder deflection (deg)	Elevator deflection (deg)	α (deg)	ϕ (deg) (a)	V (fps)	$\dot{\Omega}$ (radians/sec)
A	Normal	30	30 up	41	2d	226	2.7
A	Normal	30	0	39	3d	214	3.2
A	Normal	30	20 down	38	4d	207	3.4
A	I_X and I_Z increased 50 percent I_X	30	0	40	2u	172	3.4
B	Normal	30	30 up	36	2d	239	2.3
B	Normal	30	0	38	0	226	3.1
B	Normal	30	20 down	34	1u	222	3.3
C	Normal	30	35 up	42	1d	203	3.6
C	Normal	30	0	52	1d	171	4.2
C	Normal	30	15 down	51	1d	164	4.2
D	Normal	30	30 up	55	1u	197	2.7
D	Normal	30	0	53	3u	184	2.9
D	Normal	30	20 down	54	1u	177	3.0
E	Normal	35	25 up	41	3d	147	2.4
E	Normal	35	0	45	6d	125	3.2
E	Normal	35	25 down	41	8d	125	3.3
E	I_X and I_Z increased 206 percent I_X	35	25 up	21	3u	217	3.5
F	Normal	35	30 up	36	4u	178	3.6
F	Normal	35	0	35	1u	162	3.7
F	Normal	35	20 down	36	3d	147	2.4
F	I_X and I_Z increased 124 percent I_X	35	20 up	26	3u	167	3.0
F	I_Y and I_Z increased 30 percent I_Y	35	20 up	38	0	172	2.3

^aIn describing ϕ , u means inner wing up; d, inner wing down.

TABLE IV

FULL-SCALE PARACHUTE DIAMETERS REQUIRED FOR VARIOUS
LOCATIONS OF PARACHUTE INSTALLATIONS TO
EFFECT RECOVERY FROM THE NORMAL-
CONTROL-CONFIGURATION SPIN IN
2 TURNS BY OPENING
THE PARACHUTES

Model	Approximate diameters (ft) required with:		
	Parachute fastened to tail	Parachute fastened to outer wing tip	Parachute fastened to both wing tips
A	10.0	5	> 7
B	9.0	7	> 9
C	9.0	5	9.0
D	12.5	5	8
E	6.5	4	> 6.5
F	9.0	5	> 6

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TABLE V

EFFECT OF SIMULTANEOUSLY OPENING A TAIL PARACHUTE AND NEUTRALIZING THE RUDDER

[Normal loading condition; controls set at ailerons neutral, rudder with the spin]

Airplane	Full-scale parachute diameter (ft)	Full-scale towline length (ft)	Turns for recovery by opening parachute			Turns for recovery by opening parachute and neutralizing rudder		
			Elevator up (a)	Elevator neutral	Elevator down (a)	Elevator up	Elevator neutral	Elevator down
A	8.8	22	$2\frac{1}{2}$ to $2\frac{3}{4}$	-----	-----	$1\frac{1}{2}$ to $1\frac{3}{4}$	-----	-----
B	8.8	22	$1\frac{3}{4}$ to 2	-----	-----	$\frac{1}{2}$ to $\frac{3}{4}$	1 to $1\frac{3}{4}$	1 to $1\frac{1}{4}$
C	8.8	43	1 to $1\frac{1}{2}$	$1\frac{1}{2}$ to 4	2 to $3\frac{1}{2}$	1	$1\frac{1}{2}$ to 2	$1\frac{1}{2}$ to 2
C	7.0	43	More than 3	$3\frac{1}{2}$	$2\frac{1}{2}$ to $3\frac{1}{2}$	2	$2\frac{3}{4}$	$2\frac{3}{4}$
D	8.8	43	More than $3\frac{1}{2}$	$2\frac{1}{4}$ to $2\frac{1}{2}$	$2\frac{1}{4}$	1 to 2	$1\frac{1}{4}$ to 3	$1\frac{1}{2}$ to 2
E	7.0	35	$1\frac{1}{2}$ to $1\frac{3}{4}$	$1\frac{1}{2}$ to $3\frac{1}{4}$	2 to $4\frac{1}{2}$	1 to $1\frac{1}{2}$	$1\frac{1}{4}$ to $1\frac{1}{2}$	1 to $1\frac{1}{4}$
F	6.5	31	∞	$1\frac{1}{2}$ to 3	$2\frac{1}{4}$	$\frac{3}{4}$ to $1\frac{1}{2}$	1	1

^aThe values of the deflections of the elevator and rudder are given in table III.NATIONAL ADVISORY
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TABLE VI

EFFECT OF LOADING VARIATIONS ON TURNS FOR RECOVERY OBTAINED BY OPENING

A PARACHUTE MOUNTED ON THE OUTER WING TIP

[Controls set at ailerons neutral, rudder with the spin]

Airplane	Loading conditions	Full-scale parachute diameter (ft)	Full-scale towline length (ft)	Turns for recovery		
				Elevator up (a)	Elevator neutral	Elevator down (a)
A	Normal	7.0	10.0	1 to $1\frac{1}{4}$	1 to $1\frac{1}{2}$	$1\frac{1}{4}$ to $1\frac{1}{2}$
A	I_X and I_Z increased by 50 percent I_X	7.0	10.0	$1\frac{1}{2}$ to 2	$1\frac{3}{4}$ to 2	-----
C	Normal	5.0	17.0	$1\frac{1}{4}$ to $1\frac{1}{2}$	2	$1\frac{3}{4}$ to 2
C	I_X and I_Z increased by 115 percent I_X	5.0	17.0	More than 4	-----	-----
C	Normal	7.0	17.0	$\frac{1}{2}$ to 1	1 to $1\frac{1}{2}$	1 to $1\frac{1}{2}$
C	I_X and I_Z increased by 115 percent I_X	7.0	17.0	$1\frac{1}{2}$ to 2	-----	-----
C	-----do-----	8.8	17.0	1 to $1\frac{1}{2}$	-----	-----
E	Normal	5.6	17.3	$\frac{1}{2}$ to $\frac{3}{4}$	1	-----
E	I_X and I_Z increased by 206 percent I_X	5.6	17.3	1	-----	-----
F	Normal	5.0	15.8	1	$1\frac{1}{4}$	1 to $1\frac{1}{4}$
F	I_X and I_Z increased by 124 percent I_X	5.0	15.8	More than 6	-----	-----
F	-----do-----	6.5	15.8	1	-----	-----
F	I_Y and I_Z increased by 30 percent I_Y	6.5	15.8	$\frac{1}{2}$	$\frac{3}{4}$	1 to $1\frac{3}{4}$

^aThe values of the deflections of the elevator and rudder are given in table III.

TABLE VII

EFFECT OF LOADING VARIATIONS ON TURNS FOR RECOVERY OBTAINED BY SIMULTANEOUSLY
OPENING IDENTICAL PARACHUTES MOUNTED ON BOTH WING TIPS

[Controls set at ailerons neutral, rudder with the spin]

Airplane	Loading conditions	Full-scale parachute diameter (ft)	Full-scale towline length (ft)	Turns for recovery		
				Elevator up (a)	Elevator neutral	Elevator down (a)
C	Normal	7.0	68.0	$1\frac{1}{4}$ to $2\frac{3}{4}$	2 to $2\frac{1}{2}$	2, 3, 2
C	I_X and I_Z increased by 115 percent I_X	7.0	68.0	More than 4	-----	-----
C	Normal	8.8	17.0	$\frac{1}{2}$ to $1\frac{1}{2}$	1	1
C	I_X and I_Z increased by 115 percent I_X	8.8	17.0	1 to 2	-----	-----
E	Normal	5.6	34.6	∞	$1\frac{1}{2}$, $1\frac{3}{4}$	$1\frac{1}{2}$, $2\frac{1}{2}$
E	I_X and I_Z increased by 206 percent I_X	5.6	34.6	∞	-----	-----
F	Normal	5.0	15.8	∞	$\frac{1}{4}$, $\frac{1}{2}$	$1\frac{1}{2}$, 2
F	I_X and I_Z increased by 124 percent I_X	5.0	15.8	∞	-----	-----
F	Normal	6.5	15.8	More than 6	1	1
F	I_X and I_Z increased by 124 percent I_X	6.5	15.8	∞	-----	-----
F	I_Y and I_Z increased by 30 percent I_Y	6.5	15.8	More than 4	1 to $1\frac{1}{2}$	$\frac{3}{4}$

^a The values of the elevator and rudder deflections are given in table III.

TABLE VIII

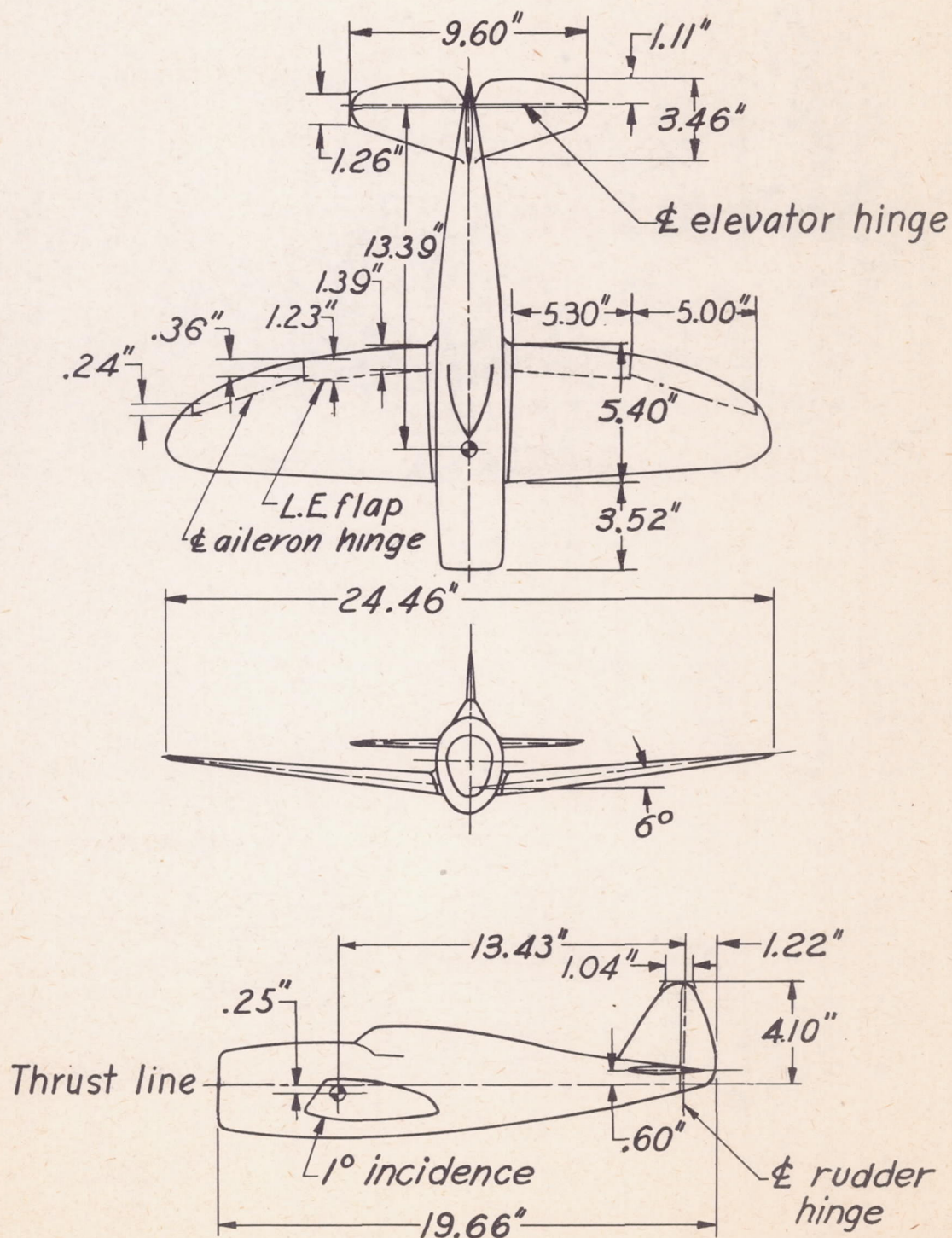
EFFECT OF LOADING VARIATIONS ON TURNS FOR RECOVERY BY SIMULTANEOUSLY
OPENING A TAIL PARACHUTE AND NEUTRALIZING THE RUDDER

[Full-scale parachute diameter, 8.8 feet; towline length, 21.8 feet (full scale);
controls set at ailerons neutral, rudder with the spin]

Airplane	Loading condition	Turns for recovery by opening parachute and neutralizing rudder		
		Elevator up (a)	Elevator neutral	Elevator down (a)
B	Normal	$\frac{1}{2}$ to $\frac{3}{4}$	1 to $1\frac{3}{4}$	1 to $1\frac{1}{4}$
B	I_X and I_Z increased by 20 percent I_X	$\frac{3}{4}$ to $1\frac{1}{2}$	1 to $2\frac{1}{2}$	1 to $1\frac{1}{4}$
B	I_X and I_Z decreased by 20 percent I_X	$\frac{1}{2}$	$1\frac{1}{2}$ to $1\frac{3}{4}$	1 to $1\frac{1}{2}$
B	I_Y and I_Z increased by 20 percent I_Y	$1\frac{1}{2}$ to $1\frac{3}{4}$	$1\frac{1}{4}$ to $1\frac{1}{2}$	$1\frac{1}{2}$ to $1\frac{3}{4}$
B	I_Y and I_Z decreased by 20 percent I_Y	1 to $1\frac{1}{2}$	$1\frac{1}{4}$ to $1\frac{1}{2}$	-----

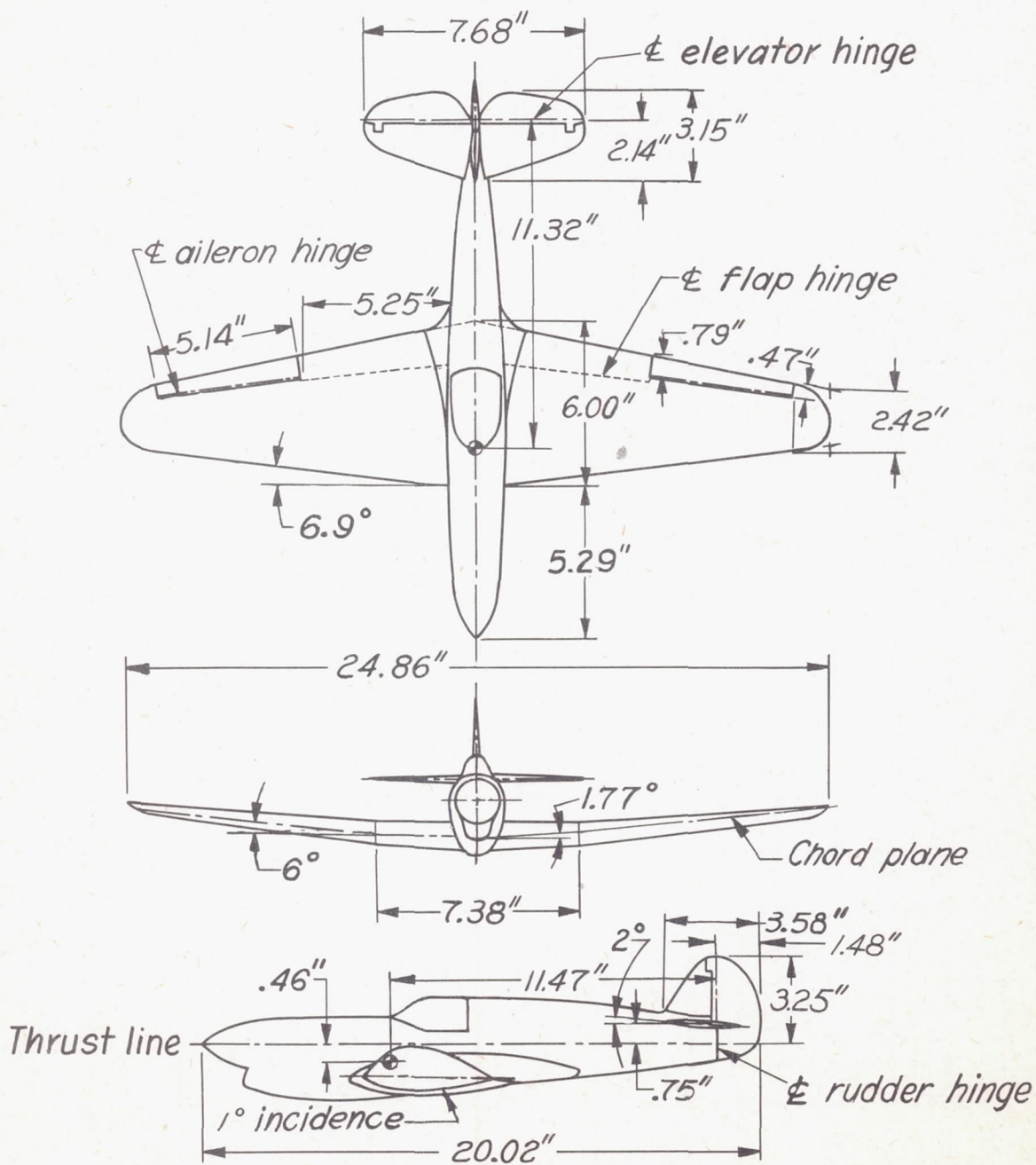
^aThe values of the deflections of the elevator and rudder are given in table III.

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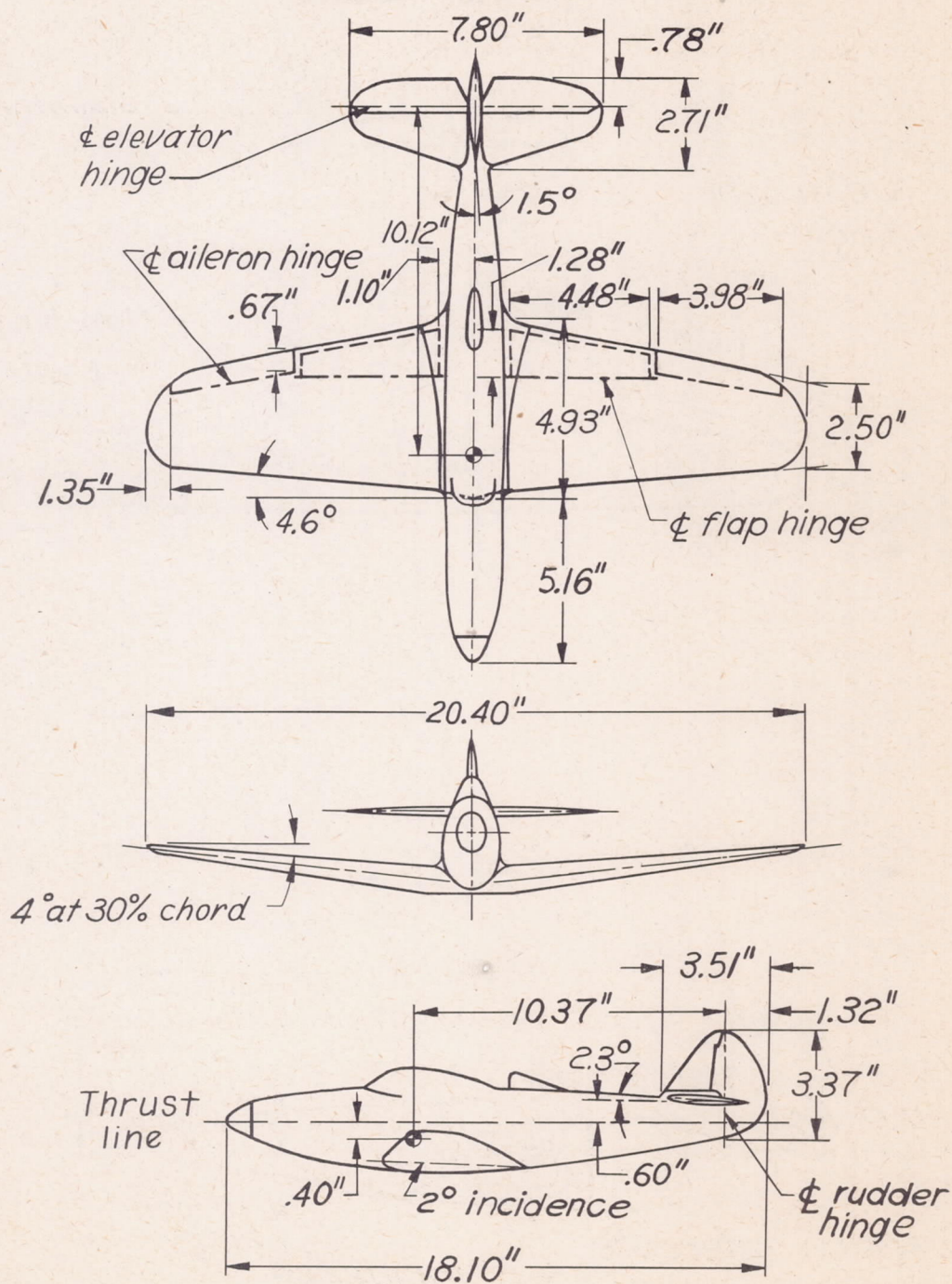
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Figure 1.- Drawing of model A used in the tests in the Langley 20-foot free-spinning tunnel. Normal loading condition.



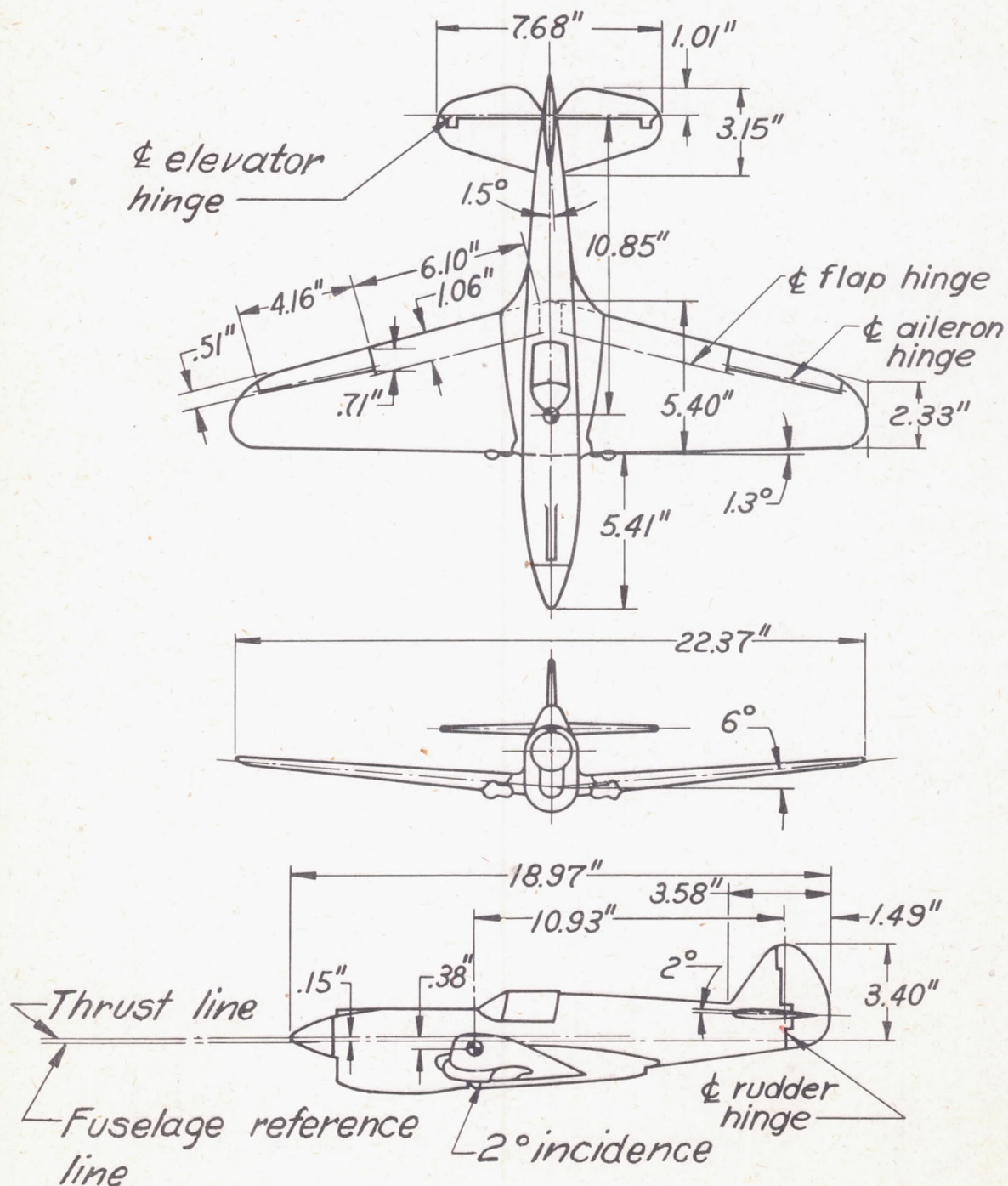
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Figure 2.- Drawing of model B used in the tests in the Langley 20-foot free-spinning tunnel. Normal loading condition.



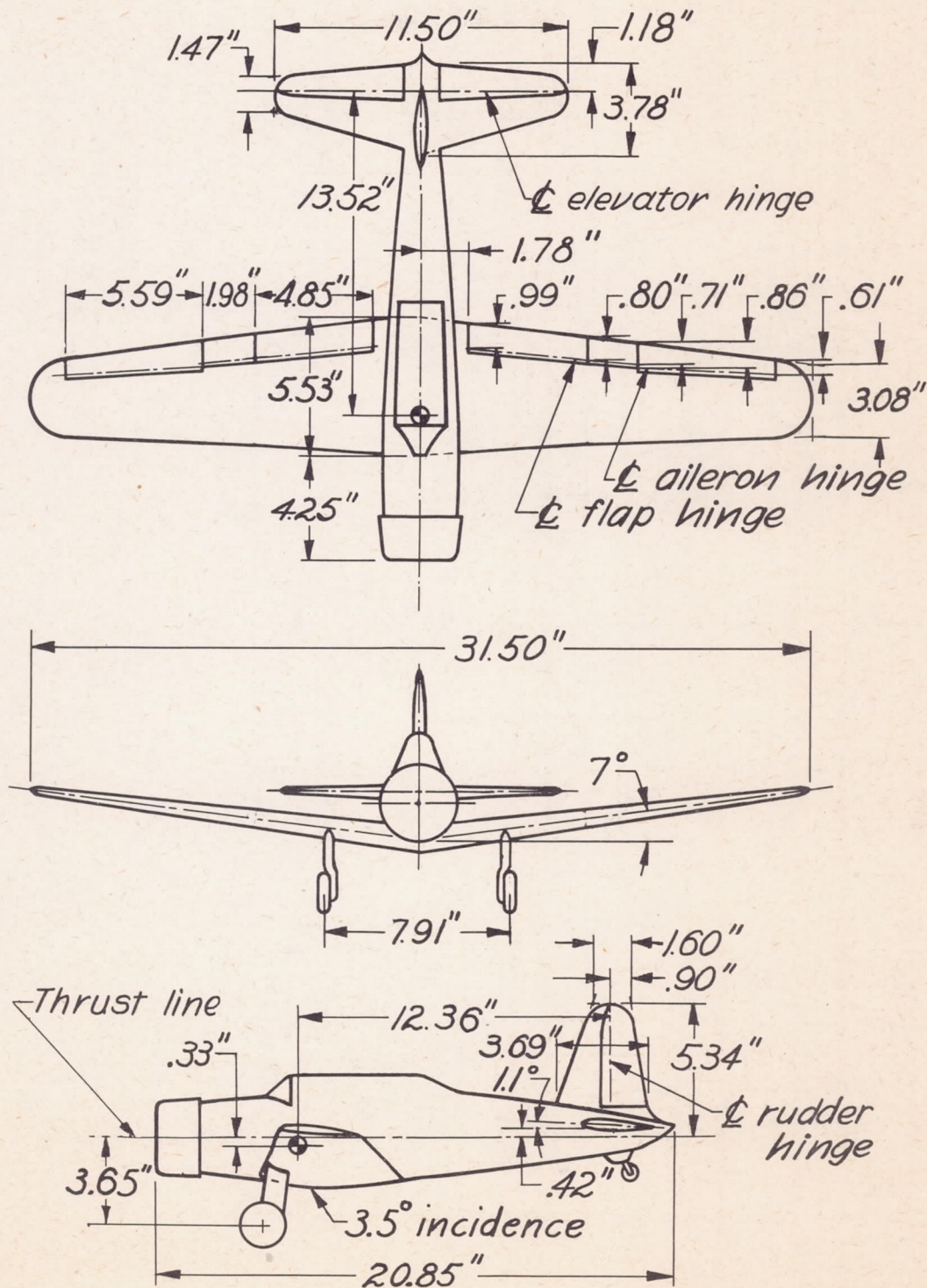
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Figure 3.- Drawing of model C used in the tests in the Langley 20-foot free-spinning tunnel. Normal loading condition.



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Figure 4.- Drawing of model D used in the tests in the Langley 20-foot free-spinning tunnel. Normal loading condition.



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Figure 5.- Drawing of model E used in the tests in the Langley 20-foot free-spinning tunnel. Normal loading condition.

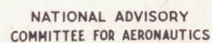
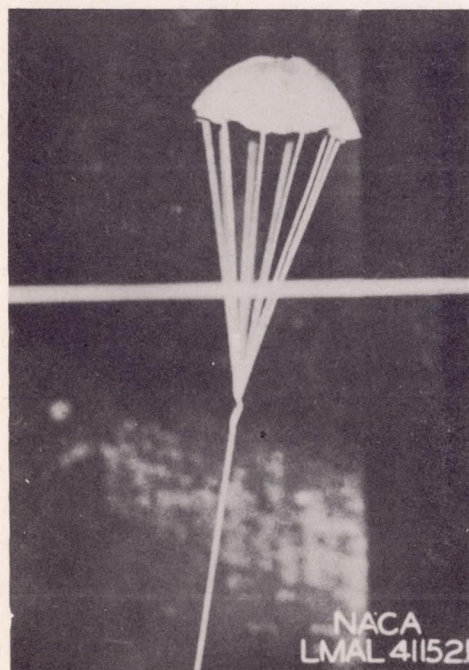
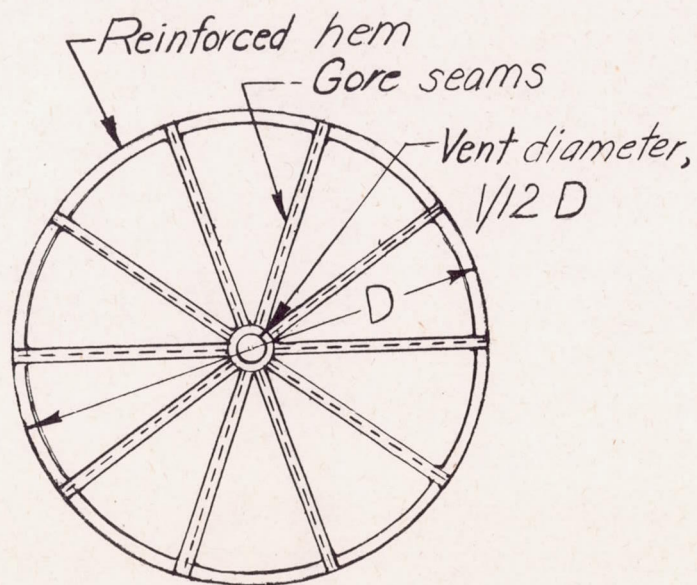


Figure 6.- Drawing of model F used in the tests in the Langley 20-foot free-spinning tunnel. Normal loading condition.



(a) Model parachute.



(b) Construction details of model parachute spread out on a flat surface.

Figure 7.- Model of a typical full-scale 10-panel circular-type parachute.

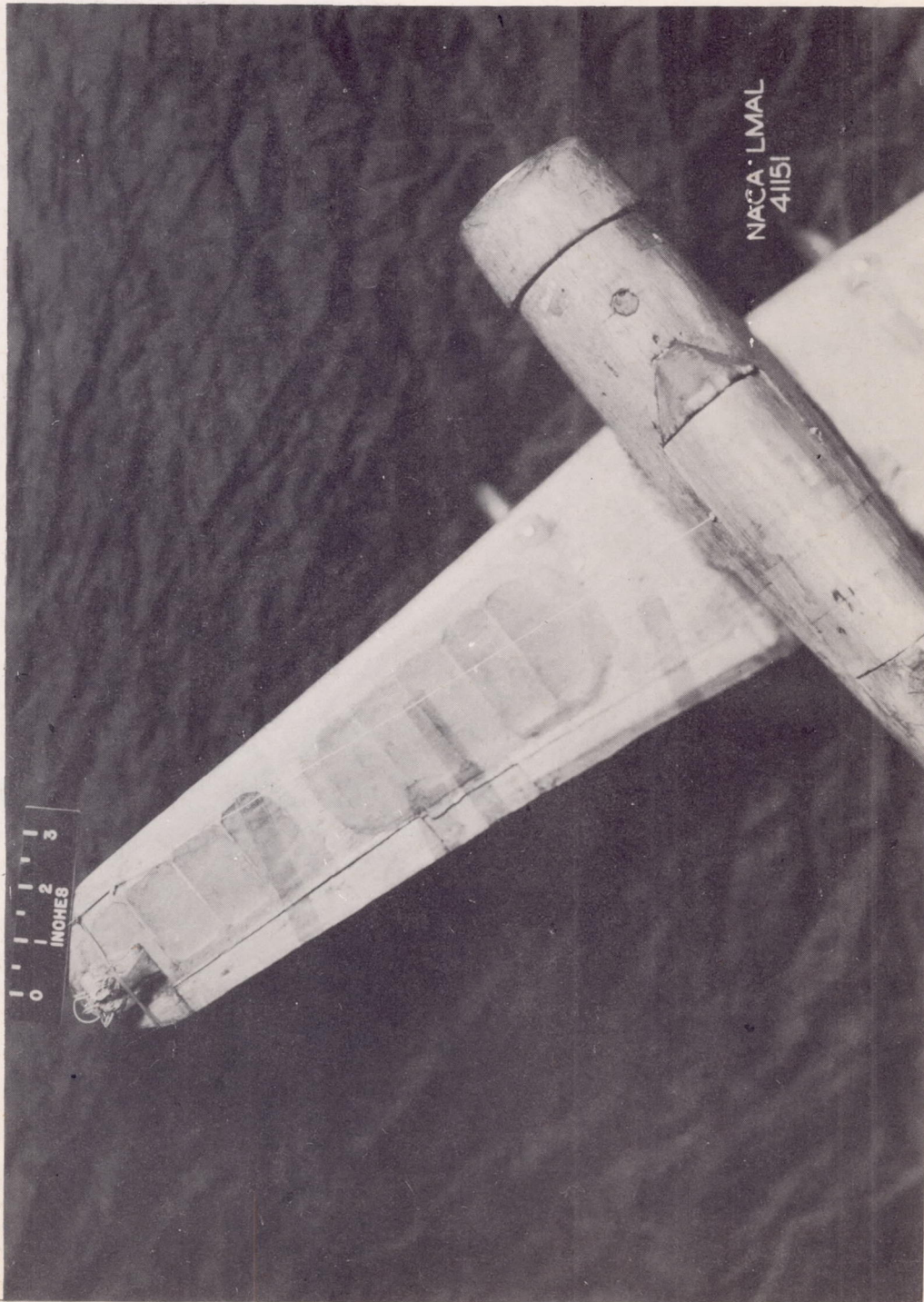


Figure 8.- Typical wing-tip-parachute installation.

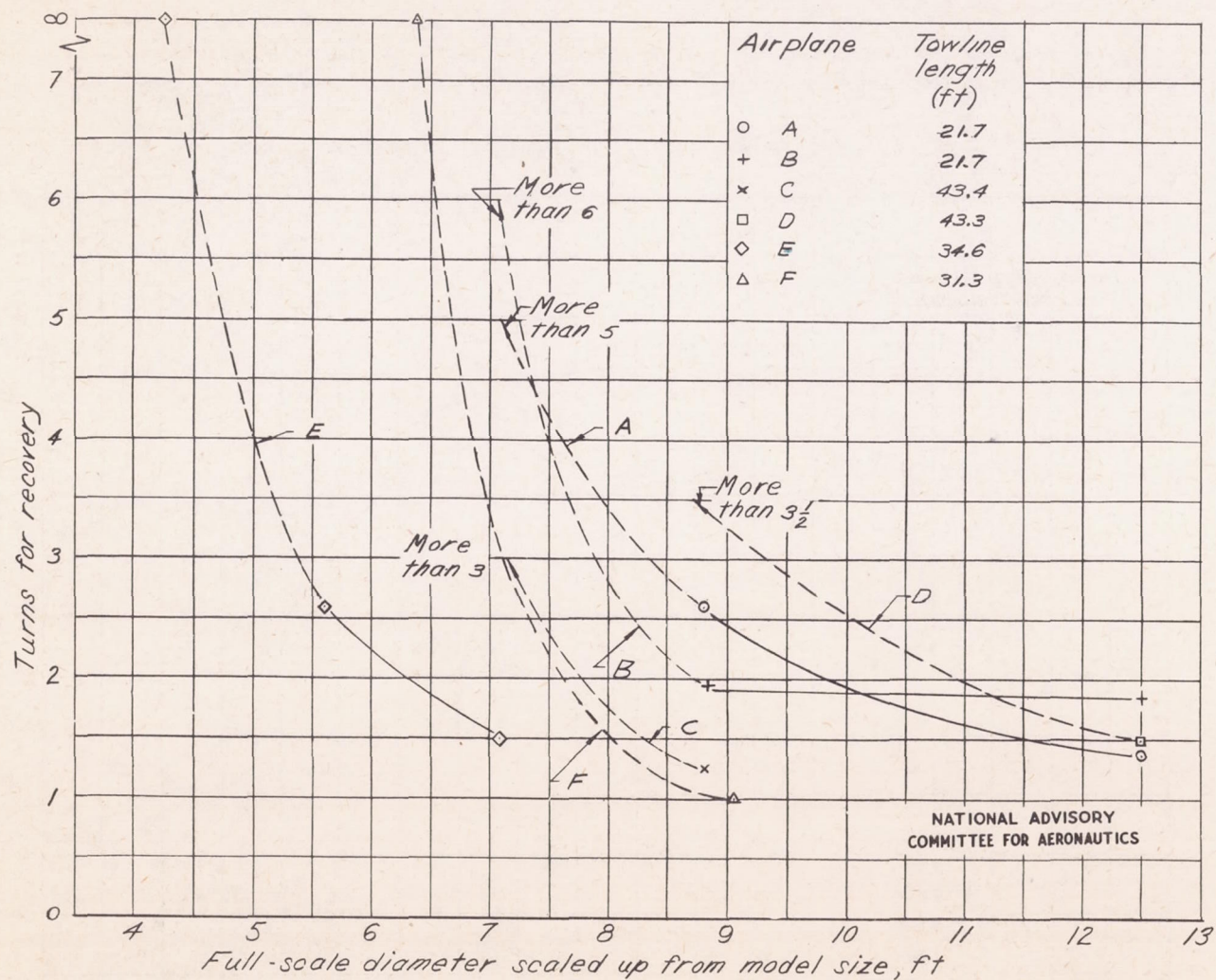


Figure 9.- The variation of turns for recovery with tail-parachute diameter; recovery attempted by opening parachute. Controls set at rudder with, ailerons neutral, elevator up.

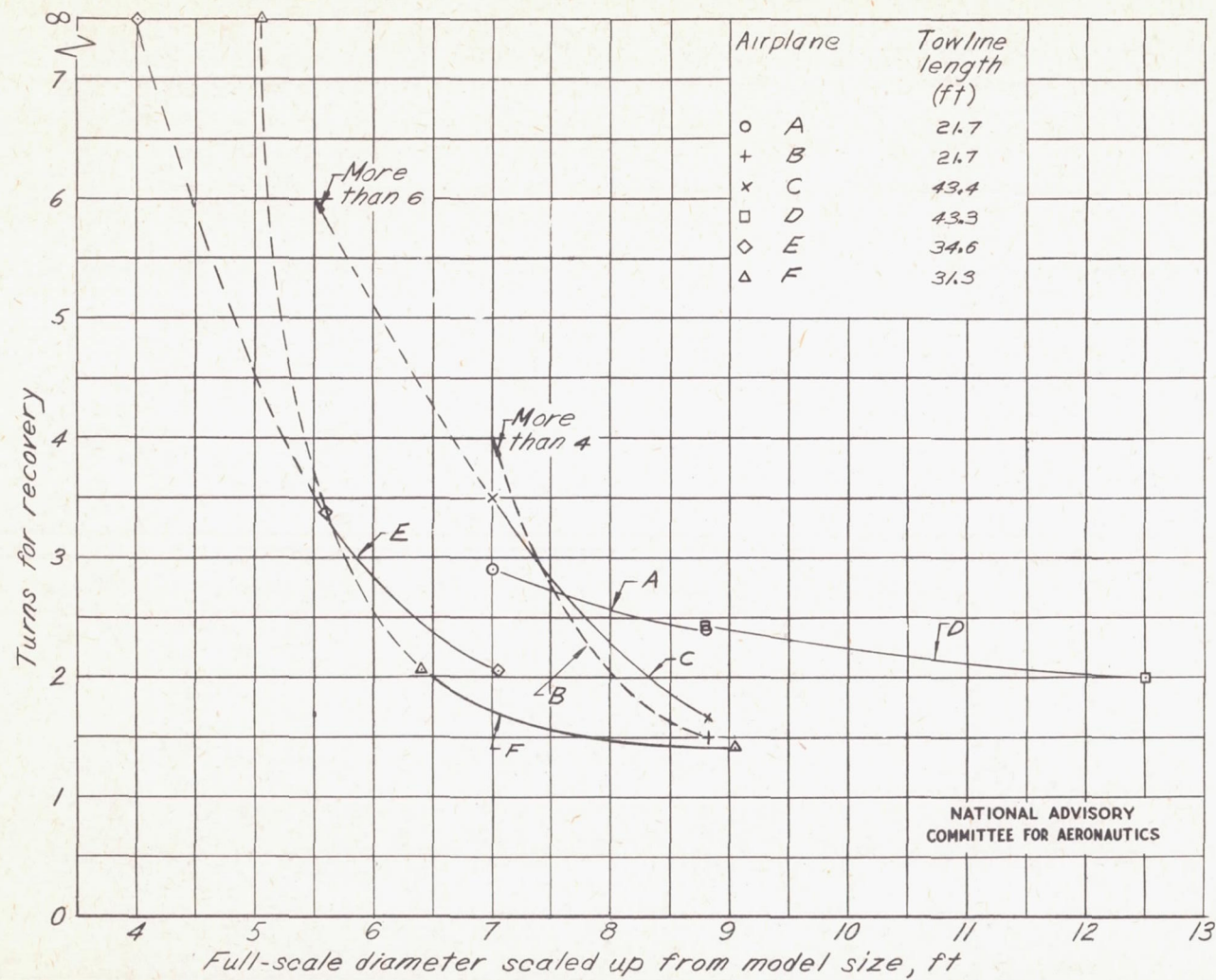


Figure 10: The variation of turns for recovery with tail-parachute diameter; recovery attempted by opening parachute. Controls set at rudder with, ailerons neutral, elevator neutral.

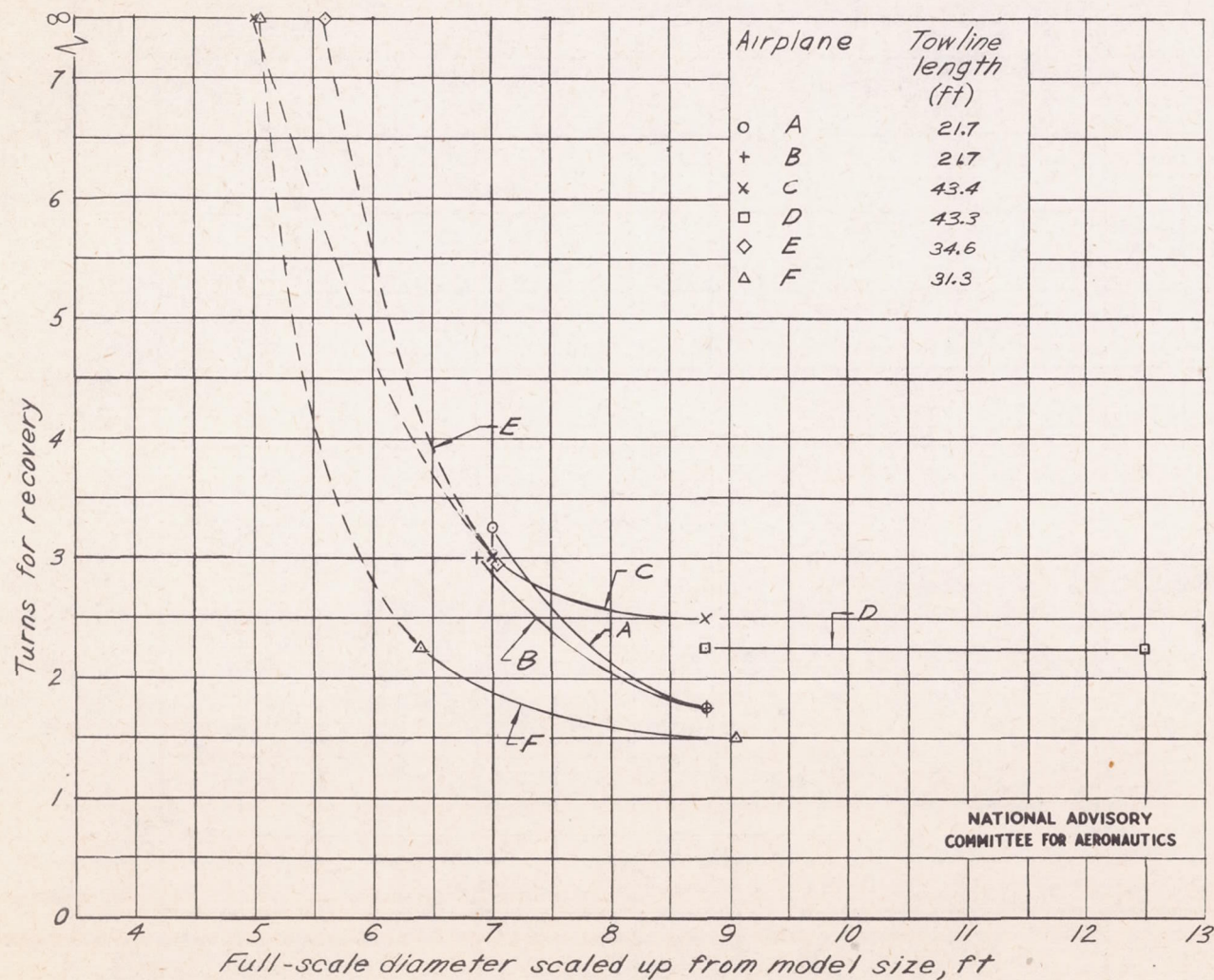


Figure 11.— The variation of turns for recovery with tail-parachute diameter; recovery attempted by opening parachute. Controls set at rudder with, ailerons neutral, elevator down.

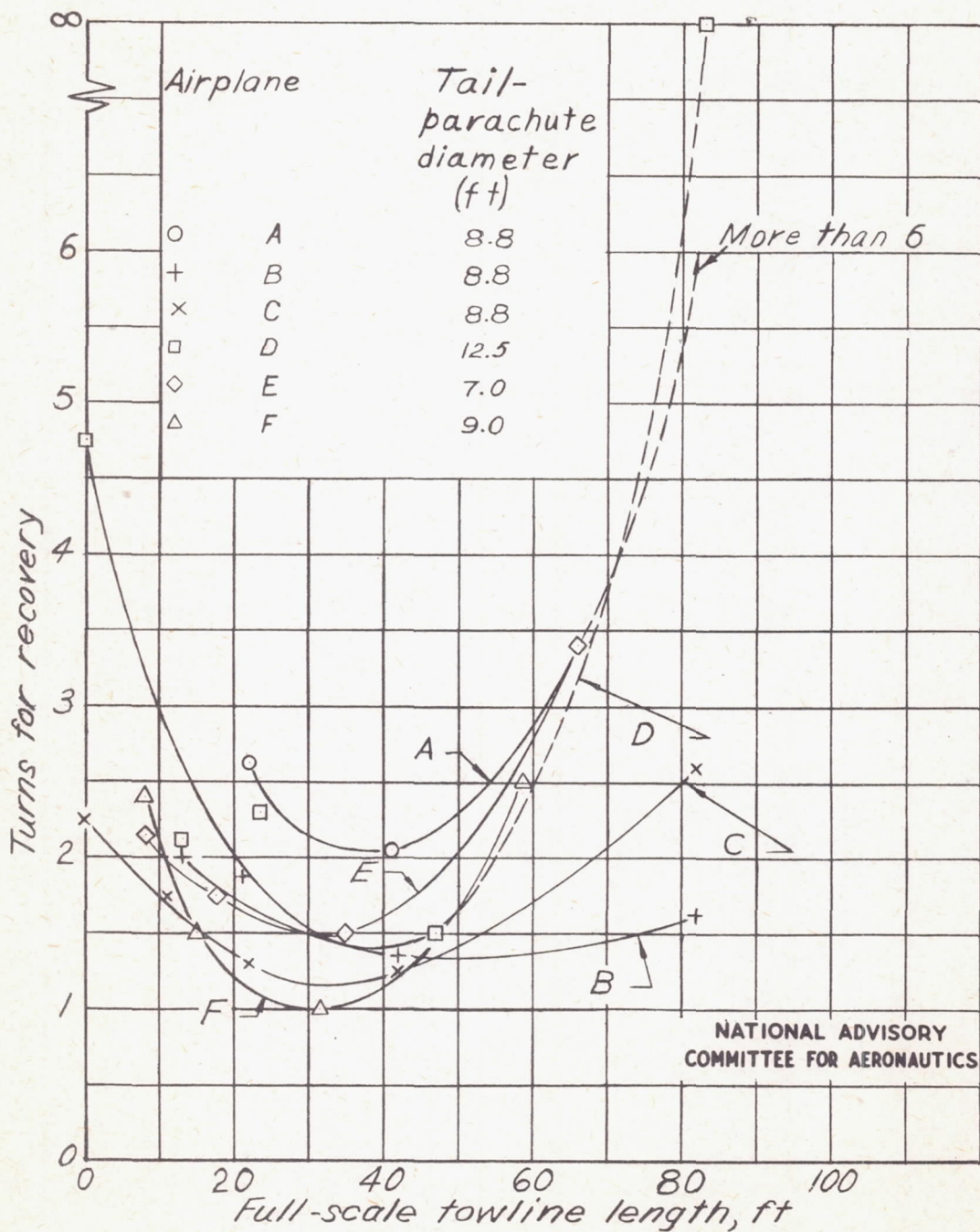


Figure 12.—The variation of turns for recovery with towline length; recovery attempted by opening tail parachute. Controls set at rudder with, ailerons neutral, elevator up.

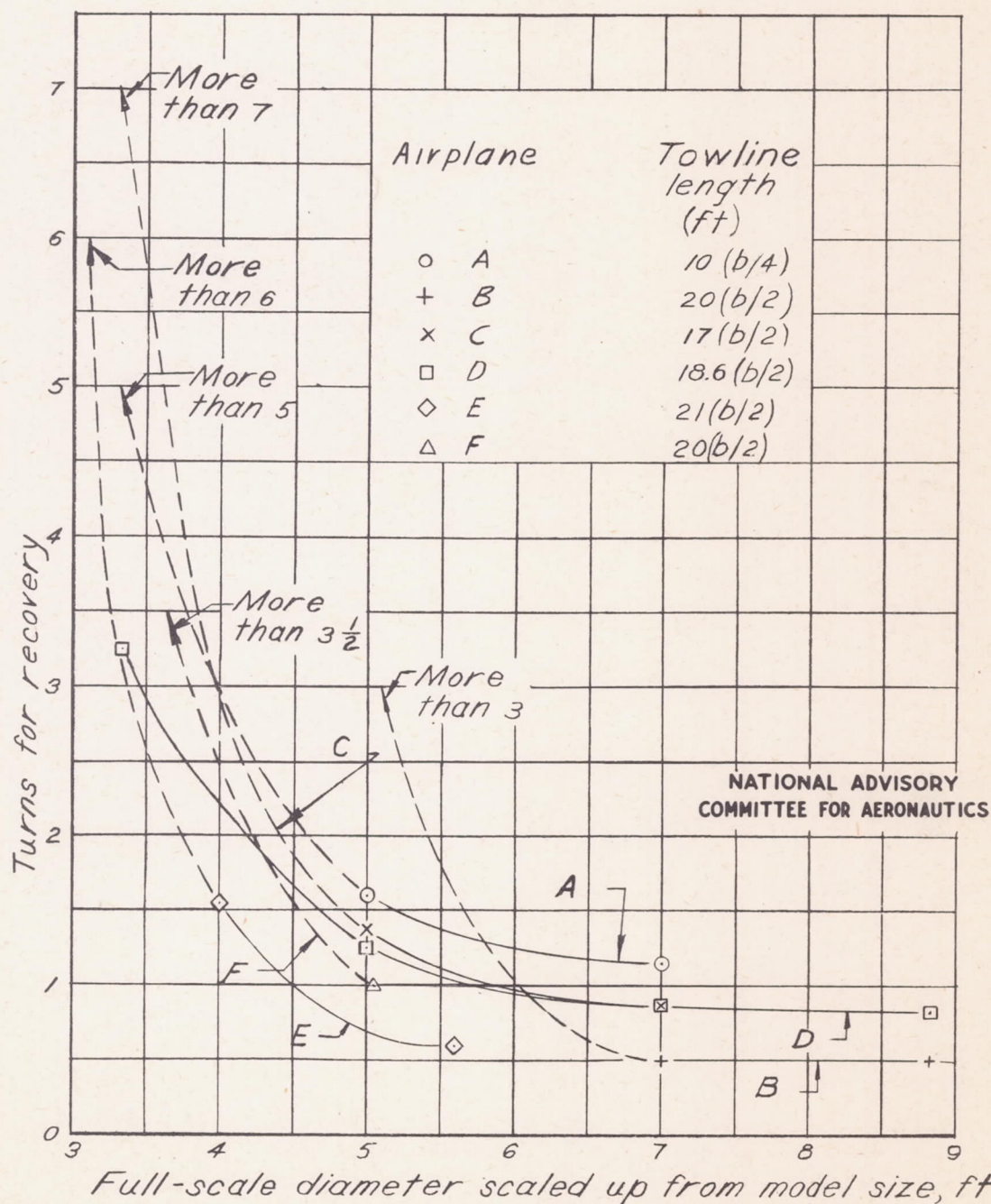


Figure 13: The variation of turns for recovery with wing-tip-parachute diameter; recovery attempted by opening parachute mounted on outer wing tip. Controls set at rudder with, ailerons neutral, elevator up.

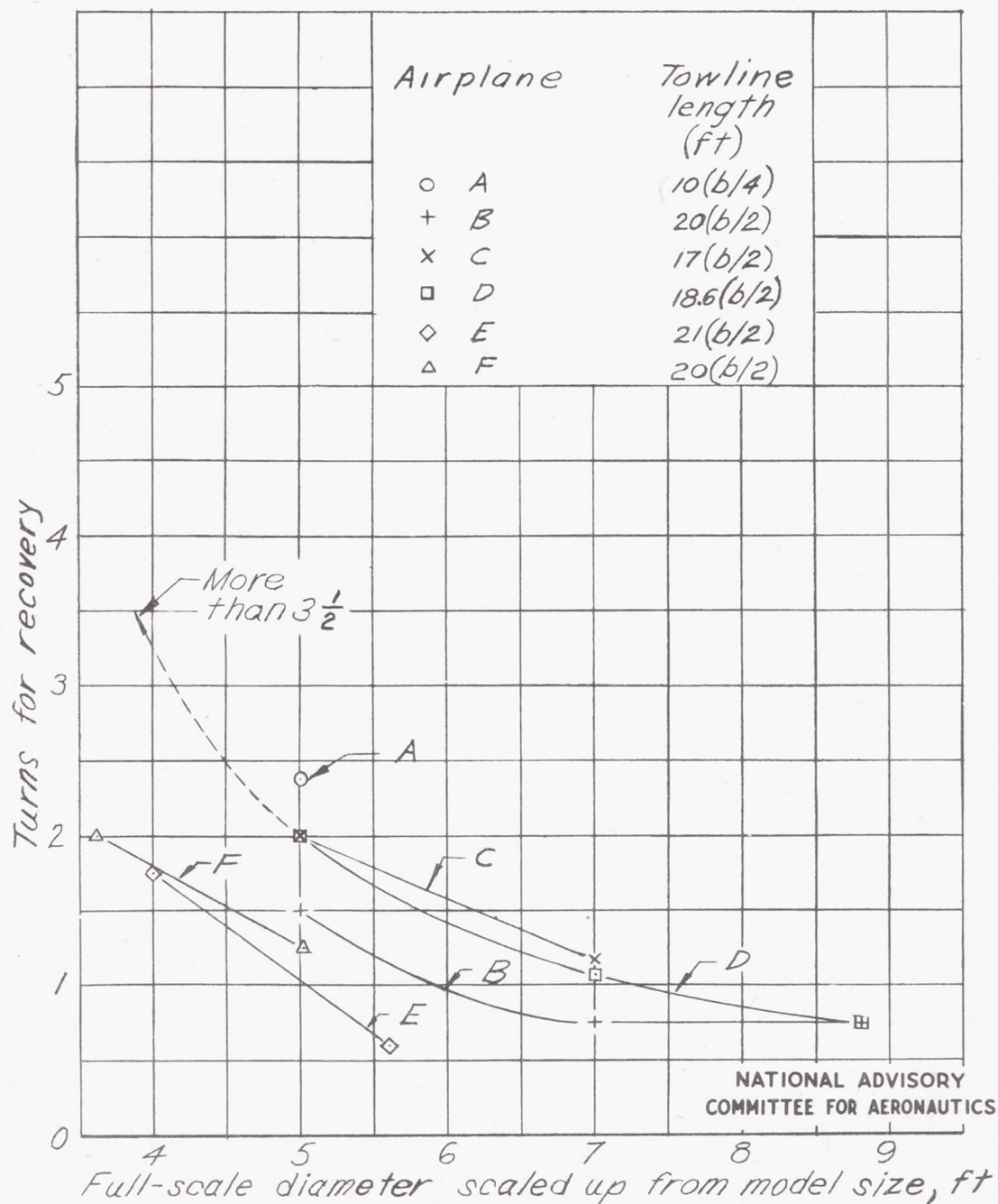


Figure 14. The variation of turns for recovery with wing-tip-parachute diameter; recovery attempted by opening parachute mounted on outer wing tip. Controls set at rudder with, ailerons neutral, elevator neutral.

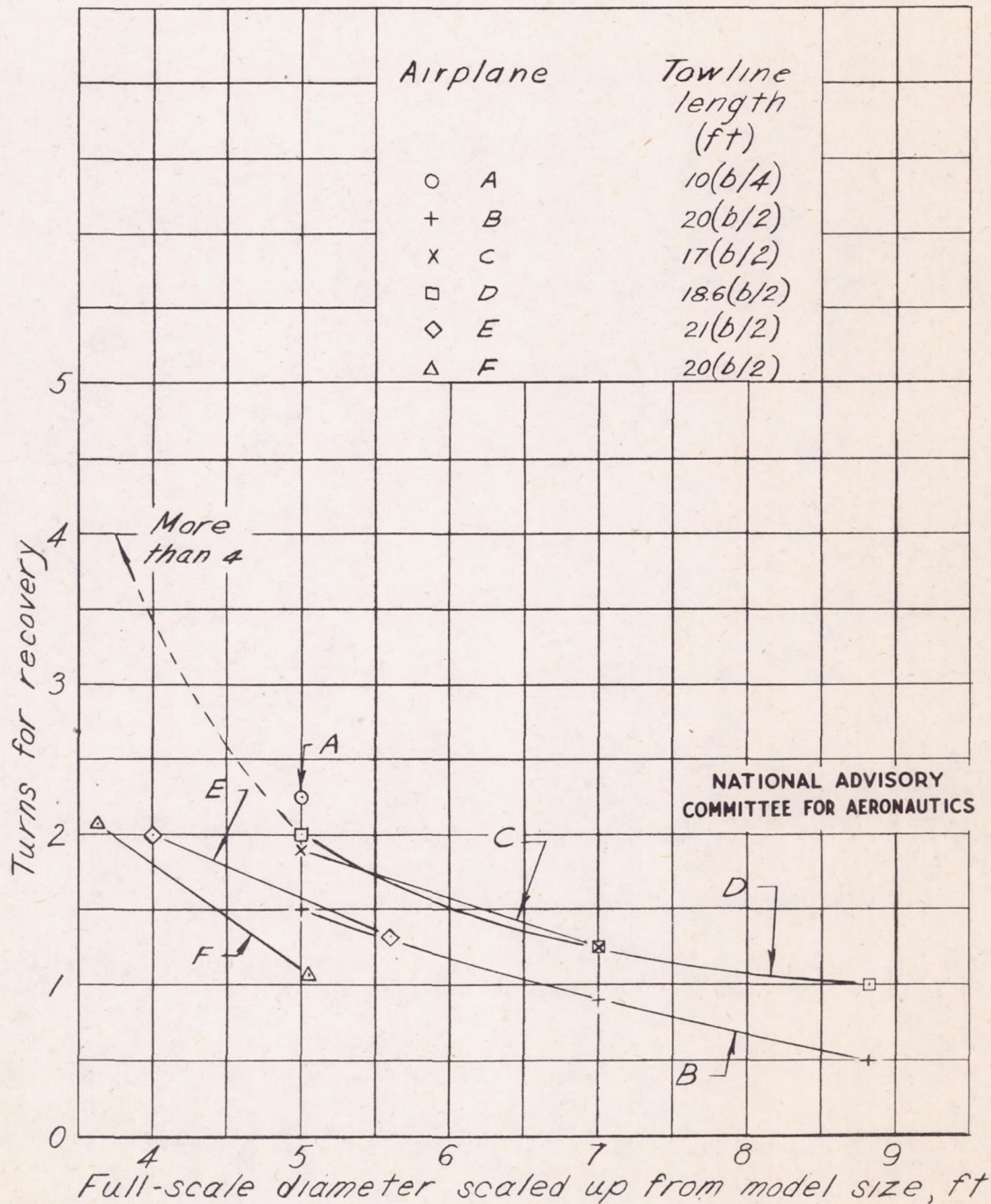


Figure 15.-The variation of turns for recovery with wing-tip-parachute diameter; recovery attempted by opening parachute mounted on outer wing tip. Controls set at rudder with, ailerons neutral, elevator down.

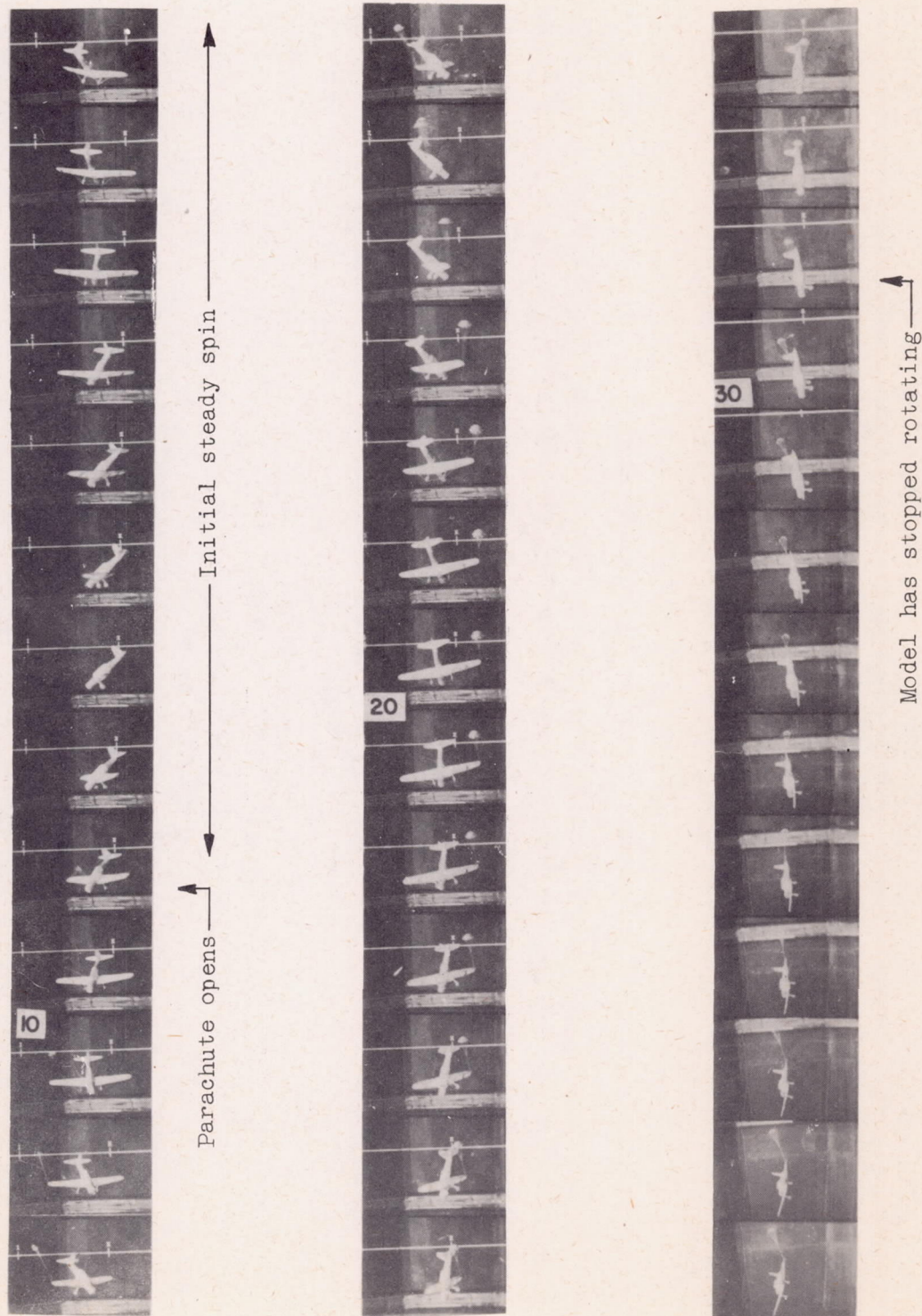


Figure 16.- Photographic record of free-spinning model tests of airplane E showing a satisfactory recovery from the spin effected by opening a 7-foot parachute (full-scale value) attached to the outer wing tip with a 17-foot towline (full-scale value).

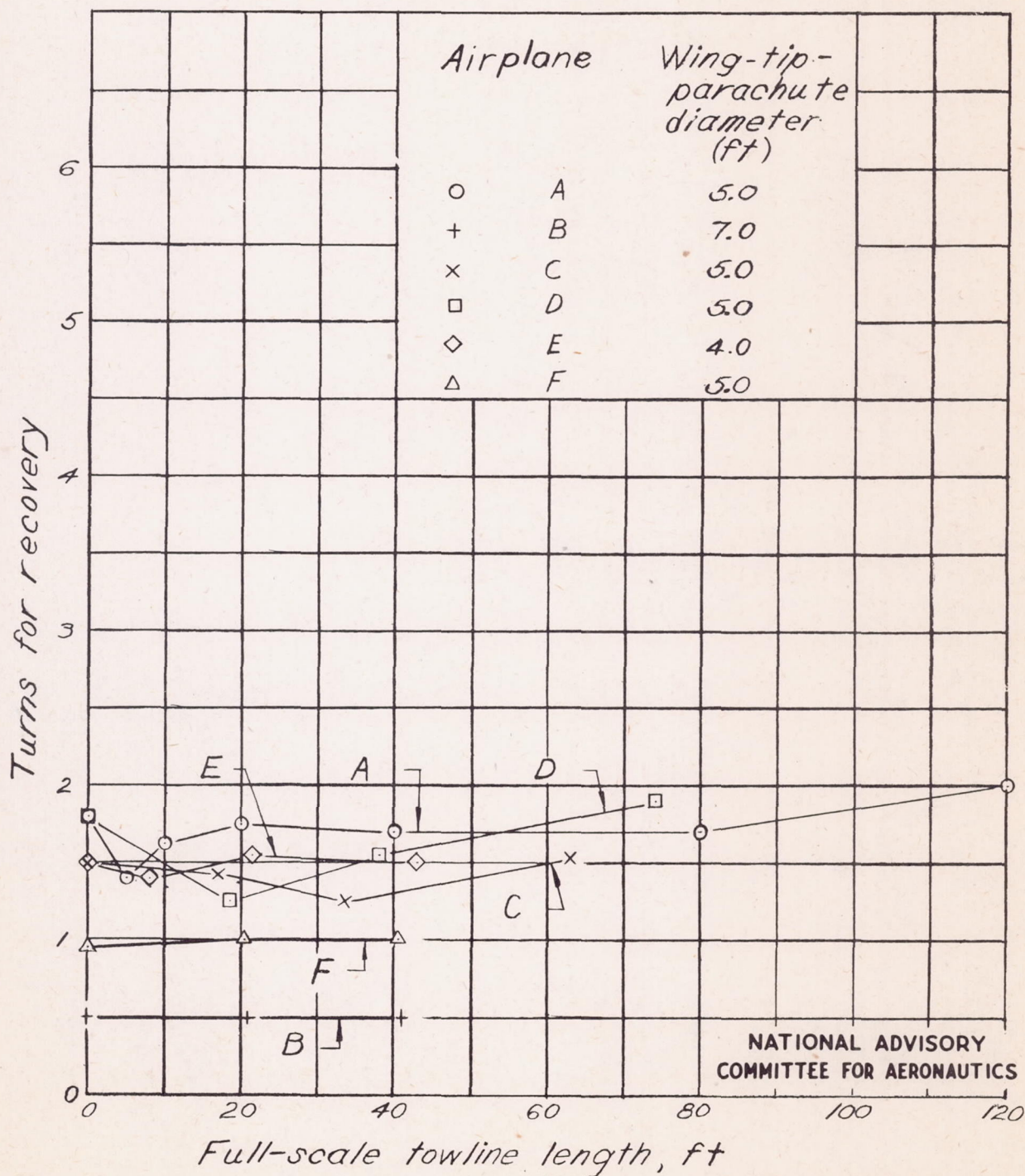


Figure 17.-The variation of turns for recovery with towline length; recovery attempted by opening parachute mounted on outer wing tip. Controls set at rudder with, ailerons neutral, elevator up.

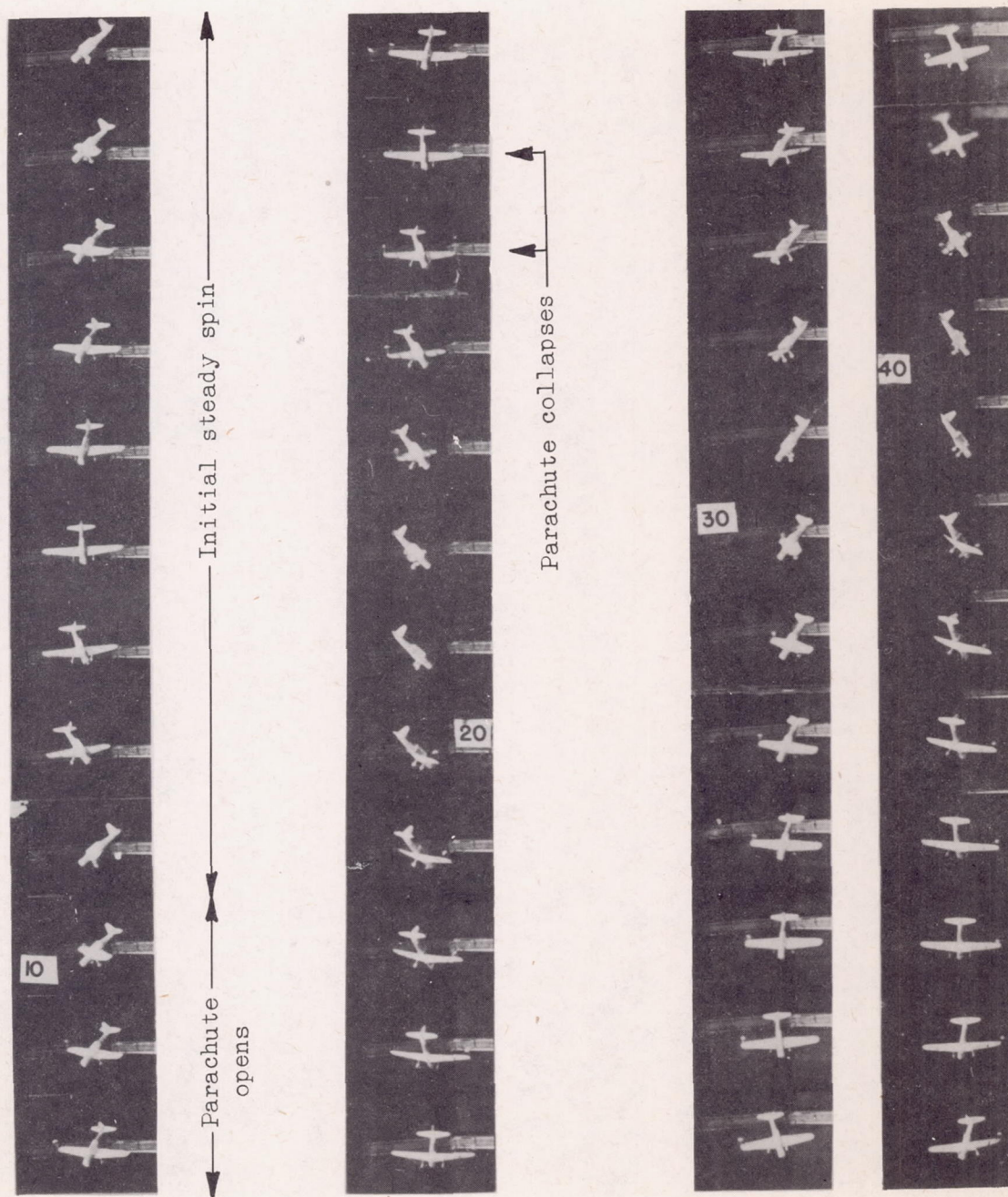


Figure 18.- Photographic record of free-spinning model tests of airplane E showing an outer-wing-tip parachute attached directly to the wing tip (no towline). Frames 14 and 15 show parachute collapse. Parachute does not effect a satisfactory recovery from the spin. Full-scale parachute diameter, 4 feet.

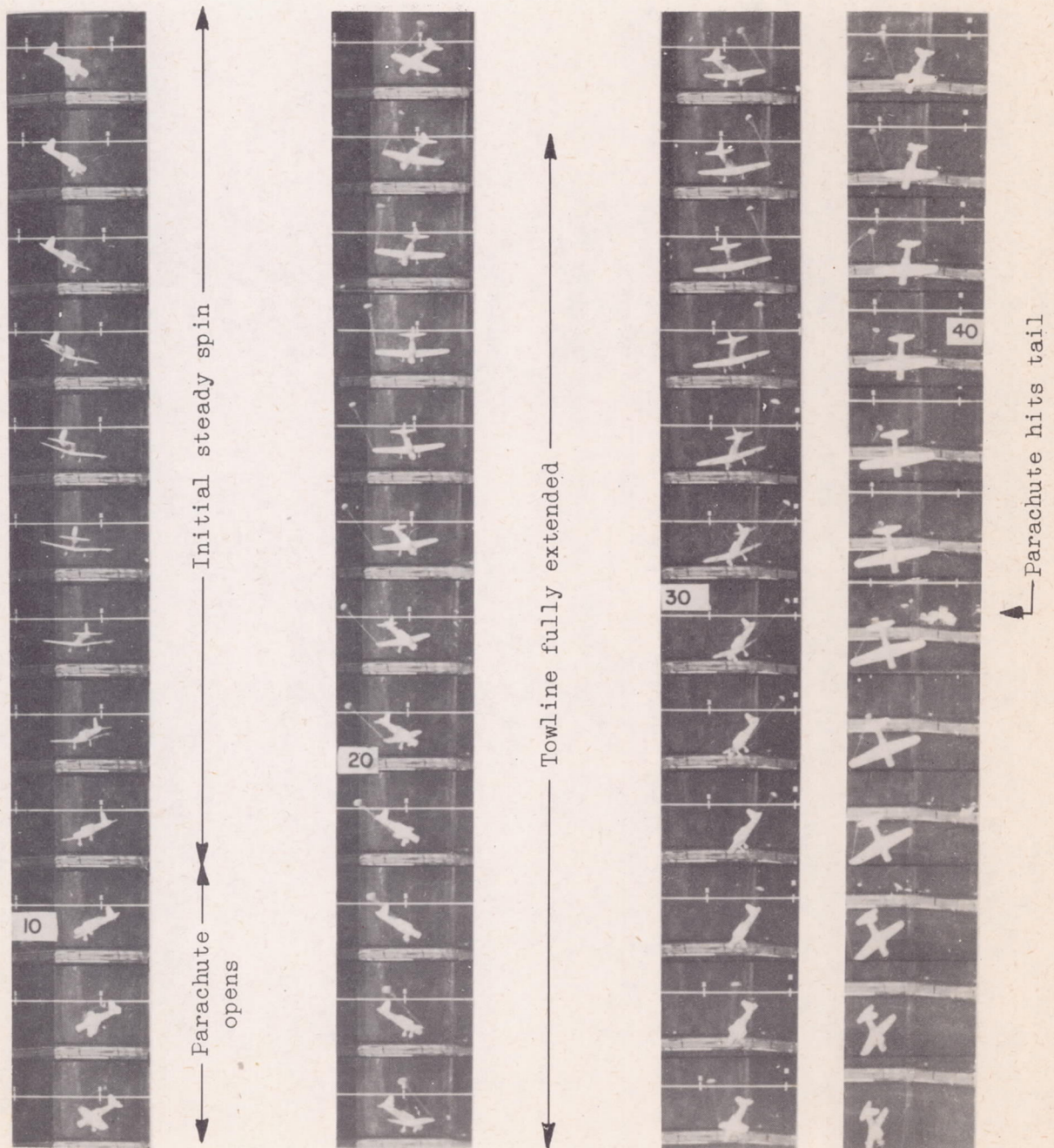


Figure 19.- Photographic record of free-spinning model tests of airplane E showing a parachute attached to the outer wing tip with a long towline hitting the tail surfaces. Parachute diameter, 4 feet; towline length, 34.5 feet; (full-scale values).

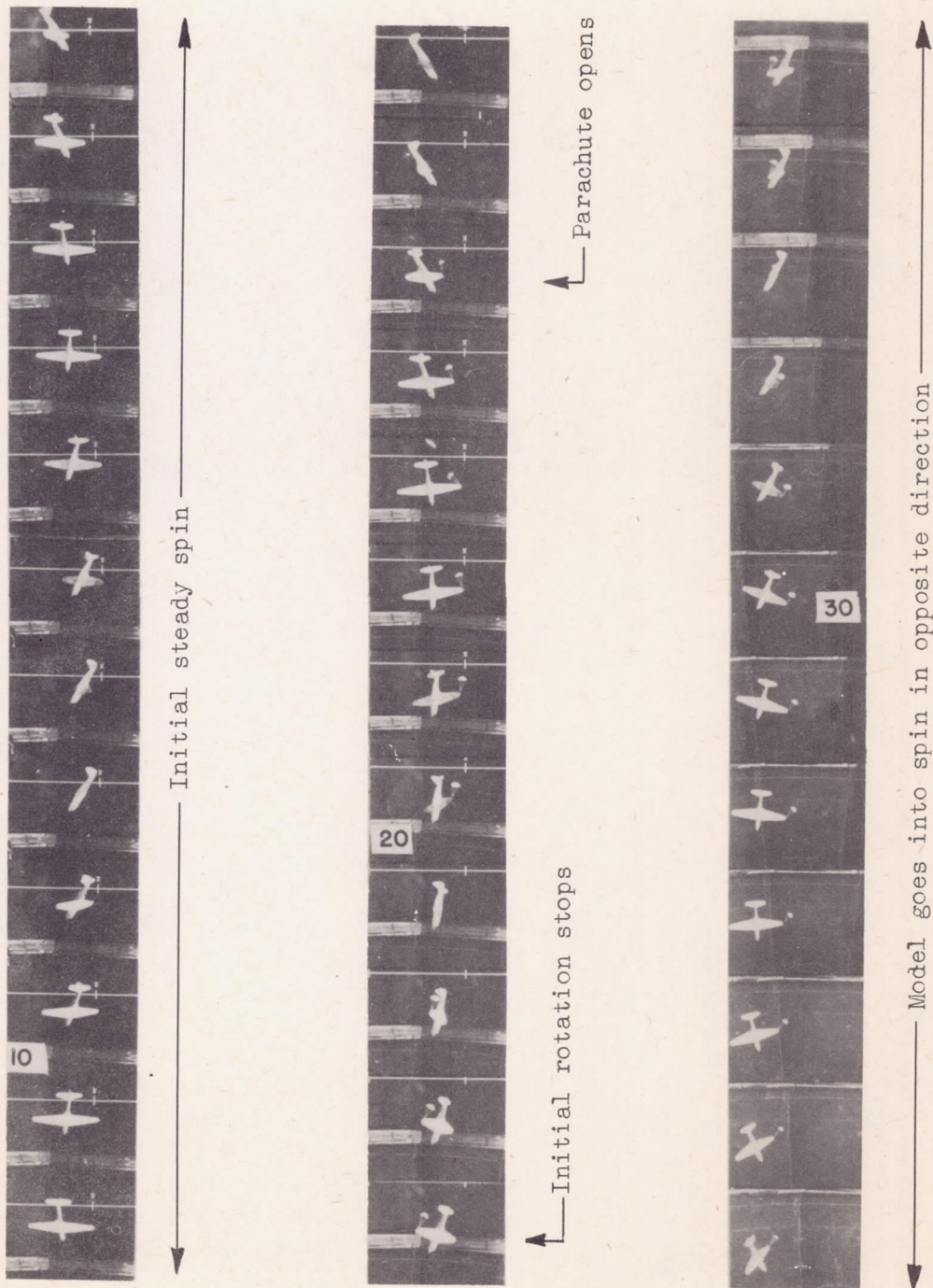


Figure 20.- Photographic record of free-spinning model tests of airplane D showing the direction of spin changing from right to left because of the large yawing moment of the wing-tip parachute. Full-scale parachute diameter, 5 feet.

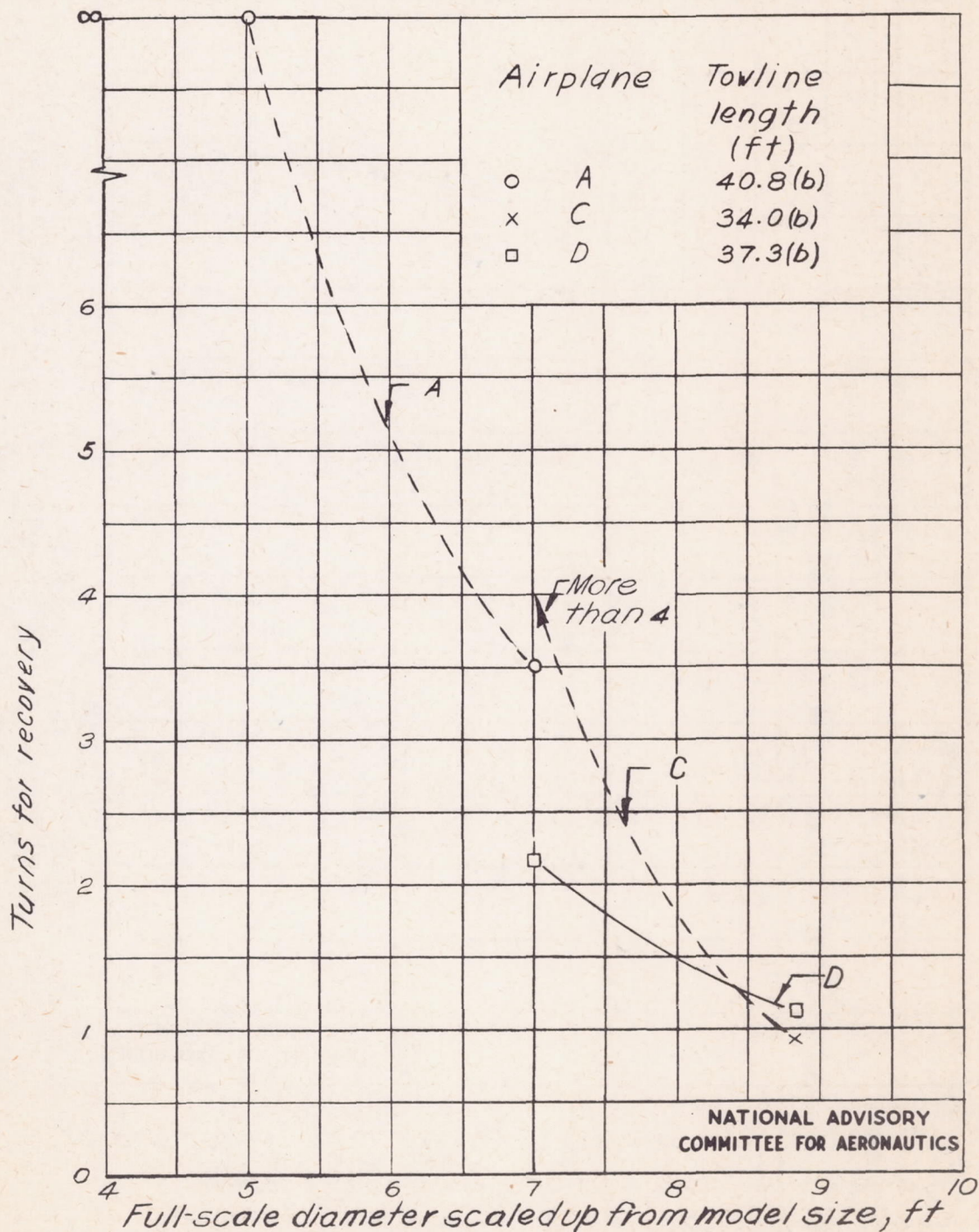
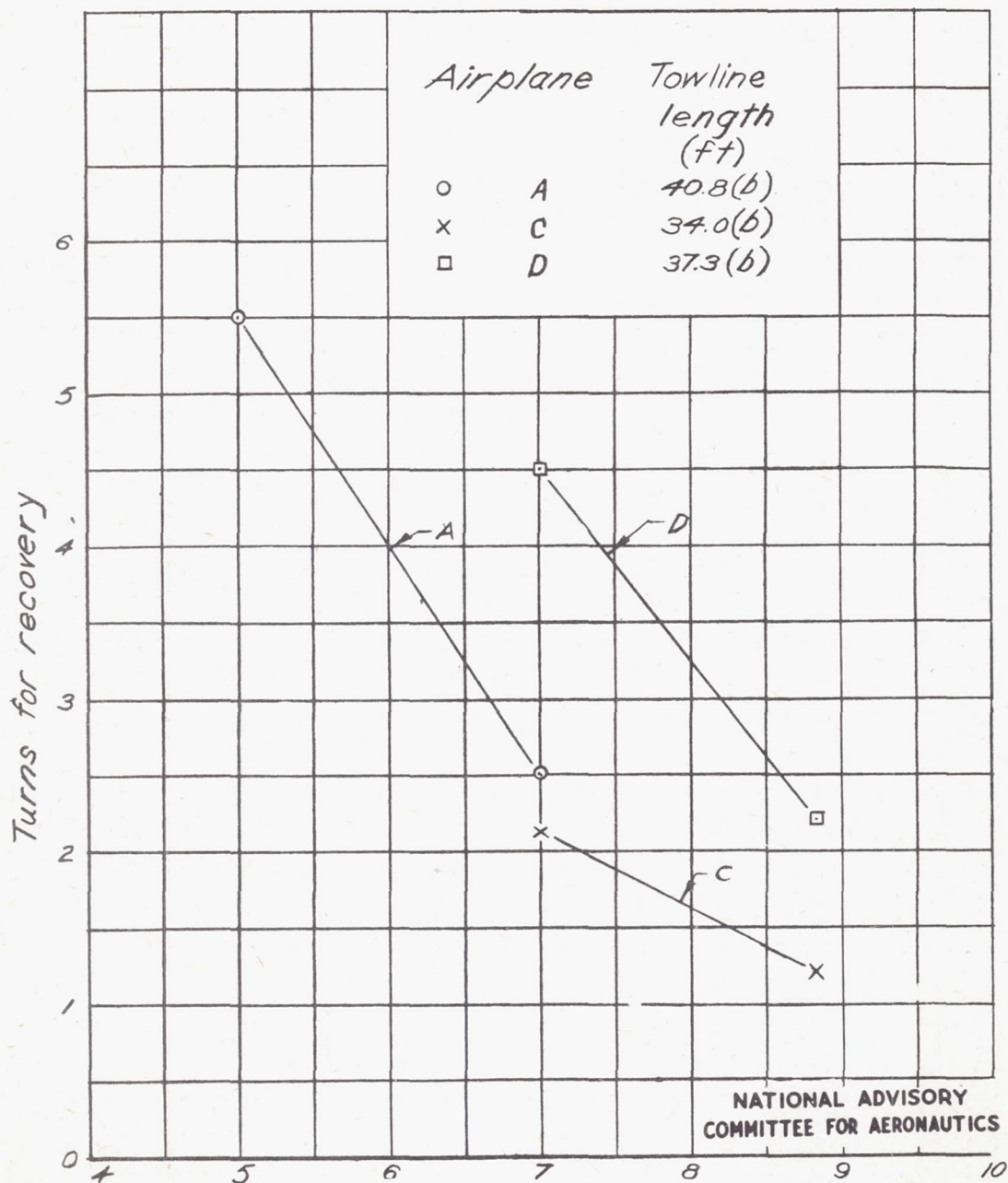
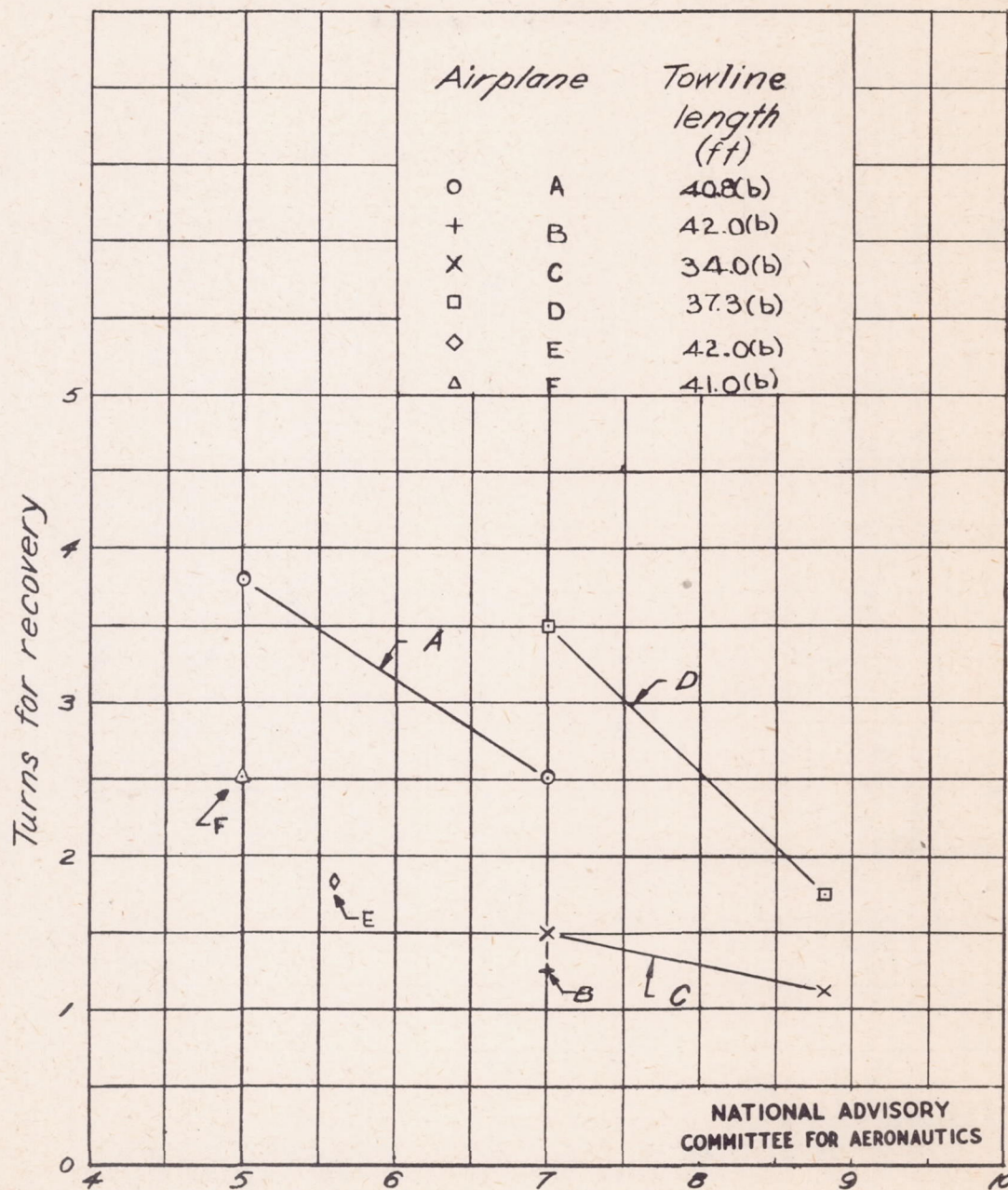


Figure 21.-The variation of turns for recovery with wing-tip-parachute diameter; recovery attempted by simultaneously opening parachutes mounted on both wing tips. Controls set at rudder with, ailerons neutral, elevator up.



Full-scale diameter scaled up from model size, ft
 Figure 22: The variation of turns for recovery with wing-tip-parachute diameter; recovery attempted by simultaneously opening parachutes mounted on both wing tips. Controls set at rudder with, ailerons neutral, elevator neutral.



Full-scale diameter scaled up from model size, ft
 Figure 23: The variation of turns for recovery with wing-tip-parachute diameter; recovery attempted by simultaneously opening parachutes mounted on both wing tips. Controls set at rudder with, ailerons neutral, elevator down.

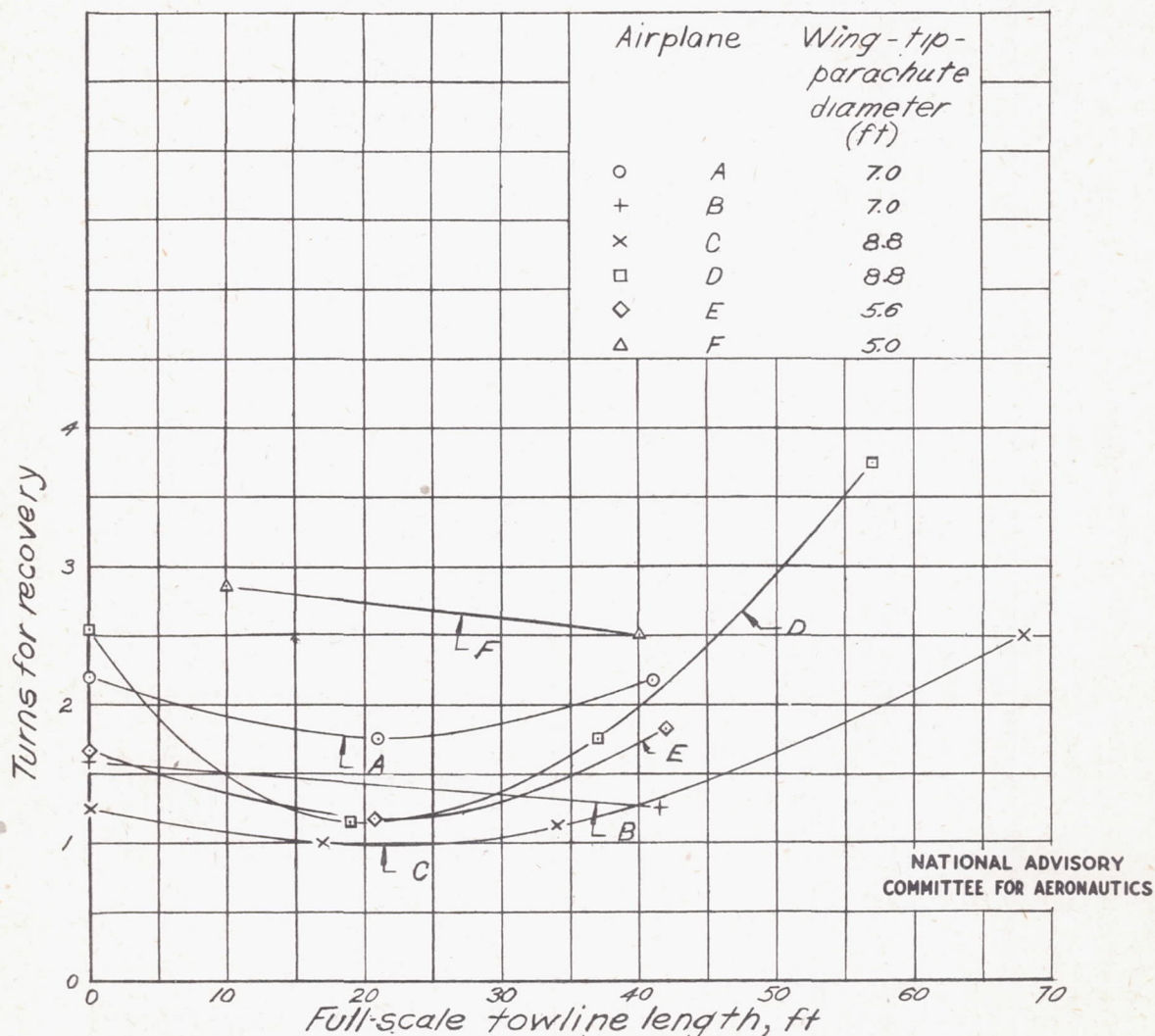


Figure 24.-The variation of turns for recovery with towline length; recovery attempted by simultaneously opening parachutes mounted on both wing tips. Controls set at rudder with, ailerons neutral, elevator down.

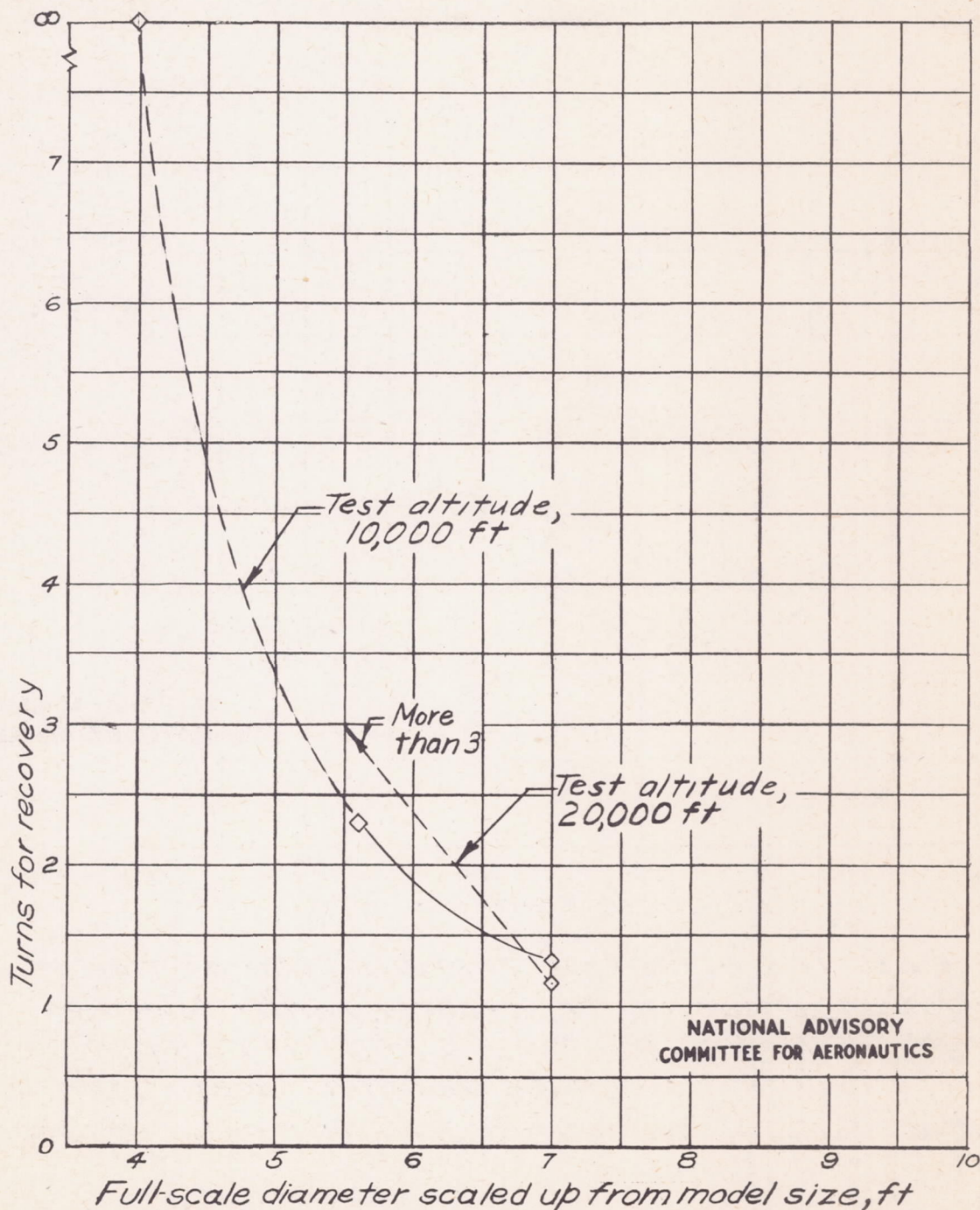


Figure 25.-The effect of test altitude on the variation of turns for recovery with parachute diameter for model E; recovery attempted by opening tail parachute. Towline length, 34.5 feet; controls set at rudder with, ailerons neutral, elevator up.

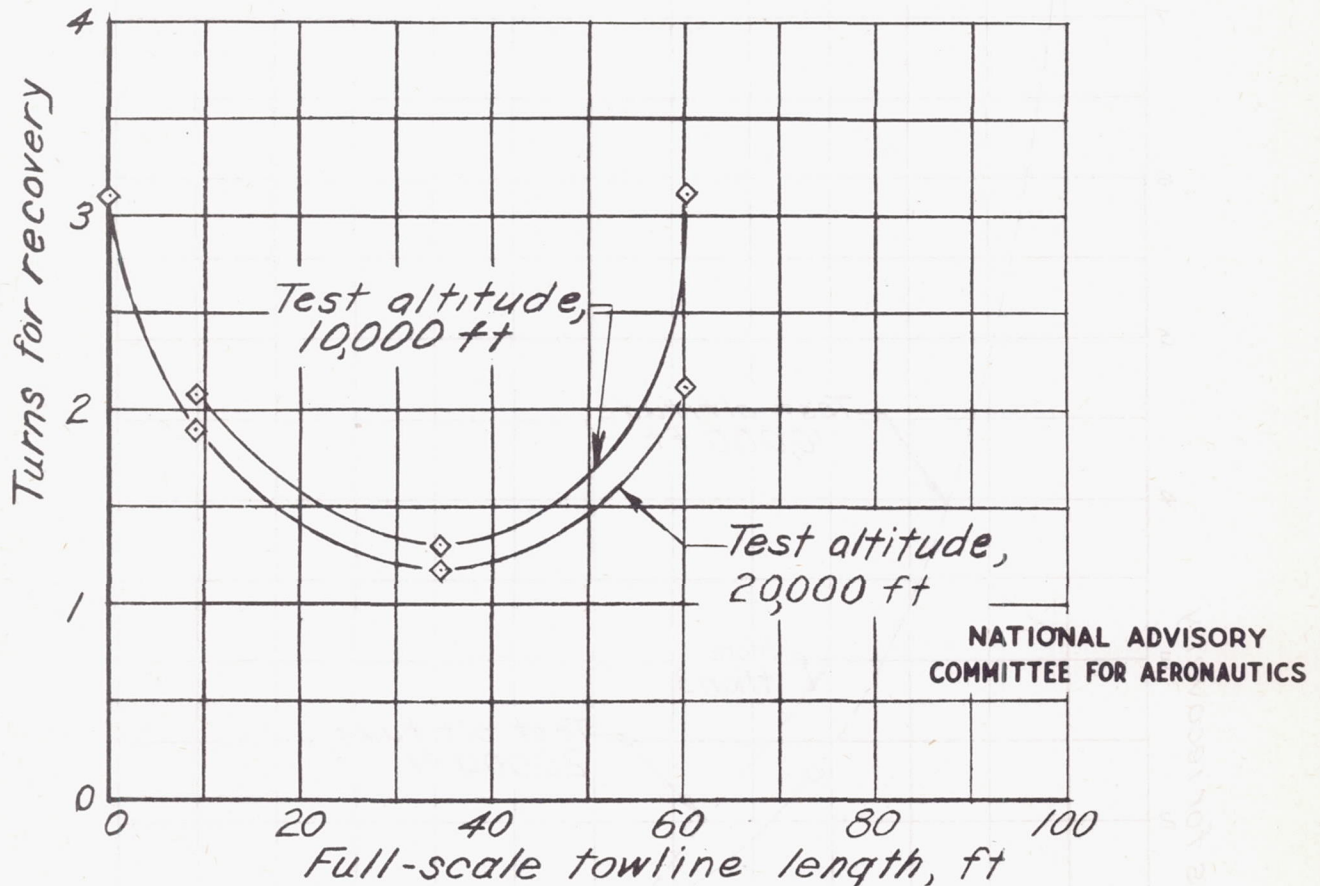


Figure 26.- The effect of test altitude on the variation of turns for recovery with towline length for model E; recovery attempted by opening tail parachute. Parachute diameter, 7 feet; controls set at rudder with, ailerons neutral, elevators up.

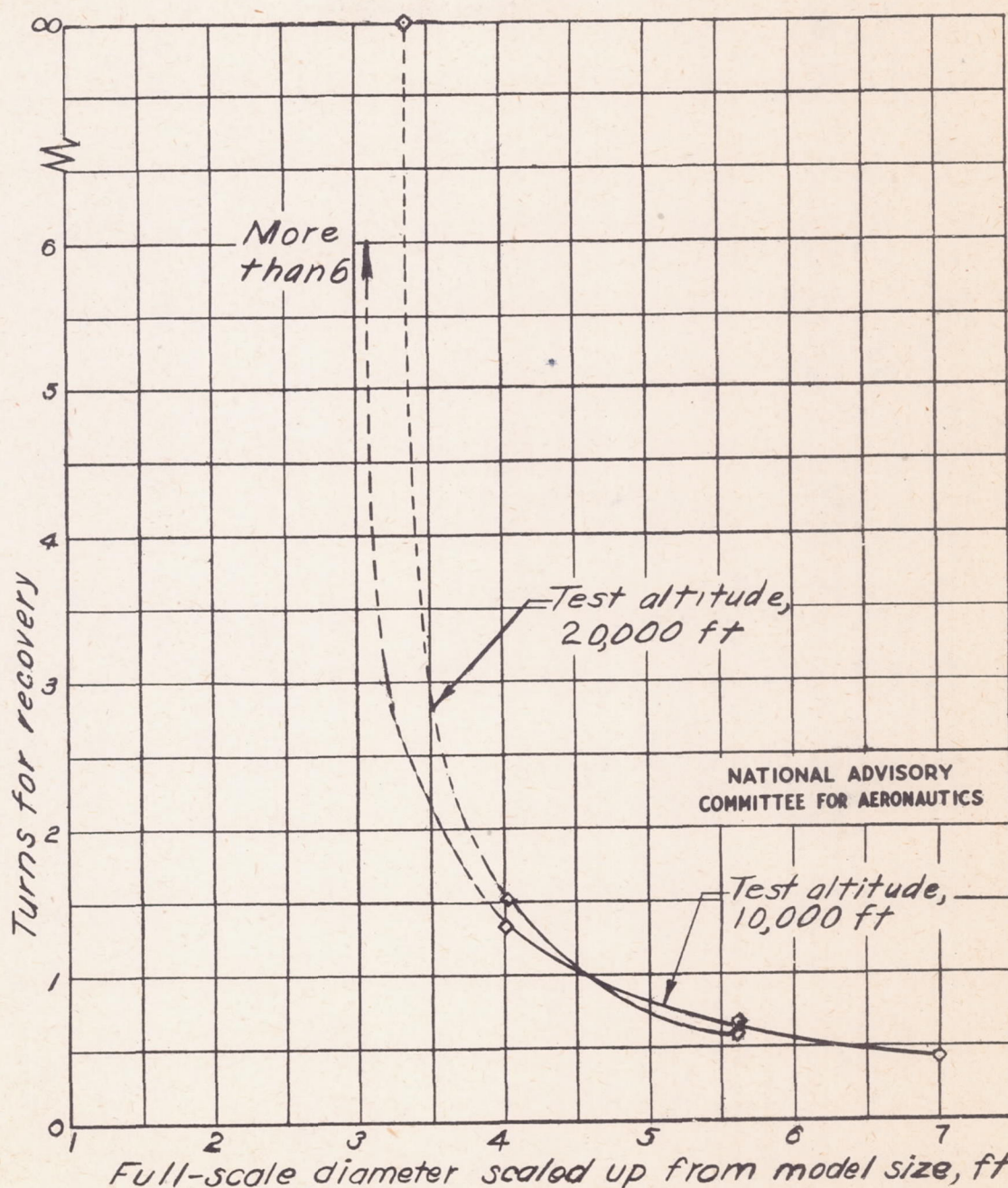


Figure 27.—The effect of test altitude on the variation of turns for recovery with parachute diameter for model E; recovery attempted by opening parachute mounted on outer wing tip. Towline length, 34.5 feet; controls set at rudder with, ailerons neutral, elevator up.